# Chapter 3: Species Accounts

In this chapter are individual accounts of the 14 species commonly found in South Carolina. They are arranged in alphabetical order by common name and provide information on identification, taxonomy, distribution, population status, habitat, behavior, reproduction, food habits, seasonal movements, longevity, survival, threats, and conservation measures. The current known distribution of each species is shown in the range maps and indicated by shaded South Carolina counties. Additionally, a summer and winter range are provided for the migratory silver-haired bat, a suspected range for the little brown bat is shown with crosshatching, and an asterisk indicates incidental records for the southeastern bat. This range map information is based on museum records, capture records maintained by the SCDNR, records from rabies testing maintained by the state's epidemiology lab, and captures recorded in published and unpublished literature such as reports and scientific literature (Menzel et al. 2003*a*, Mary Bunch, SCDNR, pers. comm.). Size measurements based off of Menzel et al. (2003*b*) are shown in Table 5. Incidental records exist of the big free-tailed bat (*Nyctinomops macrotis*) and the federally endangered Indiana bat (*Myotis sodalis*) (DiSalvo et al. 1992, NatureServe 2017). However, these species are not addressed in this document due to their rarity in the state.

Table 5: Size measurements of bat species in the southeastern US. Modified from Menzel et al. (2003*b*).

| Species | Weight (g) | Total Length (mm) | Forearm Length (mm) | Wing Length (mm) | Hind foot Length (mm) | Ear Length (mm) | Tragus Length (mm) | Wing-aspect Ratio Index [a] | Wing Loading Index [b] |
|---|---|---|---|---|---|---|---|---|---|
| Big Brown Bat | 15.3 | 111.6 | 45.9 | 138.3 | 9.6 | 16.9 | 6.1 | 2.47 | 1.97 |
| Brazilian Free-tailed Bat | 11.5 | 93.1 | 43.4 | 133.0 | 9.2 | 16.9 | 1.7 | 3.05 | 2.02 |
| Eastern Red Bat | 10.0 | 101.8 | 39.5 | 138.0 | 7.9 | 11.3 | 4.3 | 2.64 | 1.39 |
| Eastern Small-footed Bat | 4.2 | | 31.0 | | 6.0 | 14.0 | 5.0 | | |
| Evening Bat | 8.0 | 86.8 | 36.2 | 114.0 | 7.9 | 11.9 | 3.9 | 2.43 | 1.49 |
| Hoary Bat | 21.2 | 132.5 | 55.2 | 183.0 | 11.5 | 14.9 | 7.3 | 2.94 | 1.88 |
| Little Brown Bat | 6.5 | 87.4 | 37.0 | 107.7 | 8.1 | 13.5 | 5.7 | 2.23 | 1.26 |
| Northern Long-eared Bat | 8.0 | | 35.1 | | 7.2 | 15.3 | 6.8 | | |
| Northern Yellow Bat | 20.0 | 127.6 | 51.7 | 158.3 | 10.4 | 17.7 | 7.7 | 2.58 | 2.06 |
| Rafinesque's Big-eared Bat | 8.6 | 96.1 | 43.4 | 127.0 | 11.8 | 32.2 | 12.7 | 2.27 | 1.21 |
| Seminole Bat | 10.1 | 103.9 | 41.5 | 138.3 | 8.4 | 12.1 | 6.3 | 2.66 | 1.59 |
| Silver-haired Bat | 9.3 | 99.5 | 41.6 | 128.3 | 8.0 | 14.8 | 4.6 | 2.57 | 1.45 |
| Southeastern Bat | 5.7 | 86.6 | 37.1 | 115.0 | 9.6 | 13.9 | 6.7 | 2.3 | 0.99 |
| Tricolored Bat | 5.4 | 83.6 | 34.3 | 97.7 | 8.1 | 12.7 | 4.7 | 2.27 | 1.28 |

[a] Wing length/length of fifth phalanx; higher numbers indicate longer, narrower wings.
[b] [Mass/(wing length x length of fifth phalanx)] x 1,000; higher numbers indicate higher body mass per unit of wing area.

# Big Brown Bat (*Eptesicus fuscus*)

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## Description

One of the most widespread and abundant bat species in North America, the big brown bat is ubiquitous in South Carolina. This species is the third largest bat in the state, and like most bats is extremely beneficial ecologically. According to Whitaker (1995), in one summer a colony of 150 big brown bats consumes enough adult spotted cucumber beetles to prevent the production of 33 million of their larvae, a major pest of corn. This species is closely associated with humans, often roosting in human-made structures and commonly using buildings as hibernacula. Because of this, wildlife control operators are frequently hired to exclude them from homes. Big brown bats are also known for their homing ability, though the release direction from their roost played a large factor in the return rate.

## Identification

The big brown bat is a medium sized bat, with males slightly smaller than females (Burnett 1983). This species weighs 0.5 to 0.7 ounces (14 to 21 gr) and has a wingspan of 13 to 15 inches (32 to 39 cm) (Harvey et al. 2011). Big brown bats have a relatively heavy body, black ears and wing membranes, and a large head with a broad nose and powerful jaw. The pelage is dark above and light below and varies from glossy dark brown to pale. The ears and tragus are short and rounded.

## Taxonomy

Currently there are 12 recognized subspecies (Wilson and Reeder 2005) of the big brown bat, and only *Eptesicus fuscus fuscus* has been confirmed in South Carolina (Kurta and Baker 1990).

## Distribution

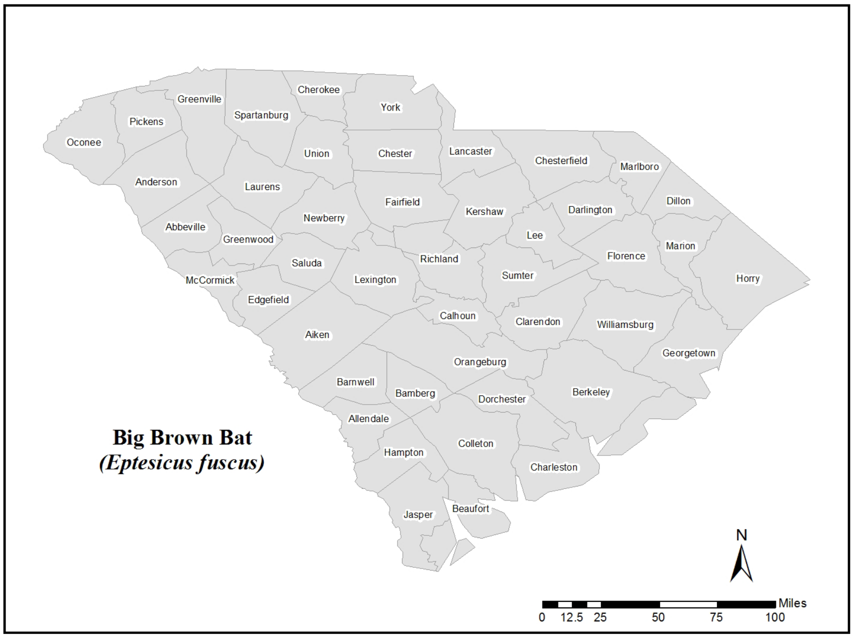
Big brown bats range from southern Canada through southern North America into South America, and are present on islands of the Caribbean (Harvey et al. 2011). In South Carolina, they are distributed statewide and found in all four physiographic provinces (M. A. Menzel et al. 2003).

## Population Status

Considered the most common bat species through most of its range, the big brown bat is ranked as Globally Secure (G5), Nationally Secure (N5) and Subnationally Secure (S5) (NatureServe 2017). It is currently classified as Least Concern (LC) on the IUCN Red List (Miller et al. 2008). However, this species is listed as a Highest Priority species in the South Carolina 2015 SWAP (SCDNR 2015) due to severe WNS-related mortality occurring in the northeast.

## General Habitat

The big brown bat is a habitat generalist found in a wide variety of habitats, ranging from lowland deserts to timberline meadows (Furlonger et al. 1987). The abundance of this species increases as one moves from the Coniferous Forest Biome to the Deciduous Forest Biome of eastern North America (Kurta et al. 1989*b*), and is also abundant in urban areas. In mountainous regions of south-




central British Columbia, males are known to occur at higher elevations than females (Fenton et al. 1980). In South Carolina, sparse vegetation was found to be the best predictor of habitat use by big brown bats (Loeb and O'Keefe 2006).

**Roosts and Roosting Behavior**

During summer, big brown bat summer roosts can be found in hollow oak (*Quercus*) and American beech (*Fagus grandifolia*) (Christian 1956, Kurta 1980). Maternity colonies were traditionally found beneath loose bark and in small cavities of pine, oak, beech, bald cypress and other trees (Bat Conservation International 2015), but now often roost in human-made structures such as houses, barns, churches, attics, bridges, behind chimneys, in hollow walls and in enclosed eaves (Barbour and Davis 1969, Kurta and Baker 1990). In South Carolina, two individuals in a bottomland hardwood swamp were tracked to a maternity colony in a hollow bald cypress (Carter 1998, Menzel 1998). Maternity colony size in the eastern US ranges from 25 to 75 adults, but can vary from five to 700 individuals elsewhere (Davis et al. 1968, Kurta 1980, Mills et al. 1975).

Colony size may depend partially on roost size as larger cavities of roost trees have been found to be correlated with larger numbers of reproductive female big brown bats (Willis et al. 2006). About 72% of adult females have strong maternity roost site or area fidelity and return to the natal roost in successive years, but only 10 to 30% of immature females do the same (Davis 1967, Brenner 1968, Mills et al. 1975).

Males may roost with females or in all-male colonies, but are most often solitary during summer (Davis et al. 1968, Barbour and Davis 1969). Generally, summer roost sites are located in buildings, hollow trees, rock crevices, tunnels, and even cliff swallow nests (Christian 1956, Barbour and Davis 1969, Kurta 1980, Kurta and Baker 1990). Males may join nursery groups to form large late-summer colonies when young are able to fly (Barbour and Davis 1969). Torpor is regularly used during summer while day roosting by females. Males also use torpor, but they enter it more deeply and use it more often than reproductive females (Hamilton and Barclay 1994, Lausen and Barclay 2003). Night roosts may include garages, breezeways, and house porches (Harvey et al. 2011). By August, summer colonies begin to disperse (Barbour and Davis 1969).

During winter when the weather is extremely cold, this species can be found hibernating in caves, mines, rock crevices, storm sewers, and in attics, basements, and wall spaces of buildings (Goehring 1954, Barbour and Davis 1969, Vonhof 1995, M. A. Menzel et al. 2003).

In fact, buildings are considered the most important hibernacula for big brown bats in northwestern US, who may lose 25% of their pre-hibernation body weight by the end of the hibernation period (Nagorsen and Brigham 1993, Maser 1998). They are known to enter and leave their hibernacula throughout the winter (Mumford 1958). Winter colonies rarely include more than a few hundred individuals, but usually they are solitary or found in small groups. Both sexes have been known to hibernate together (Whitaker and Gummer 2000). However, not much is known about the roost habits of big brown bats during winter in South Carolina.

**Reproduction**

Mating occurs between September and March (Mumford 1958, Phillips 1966), and sperm is stored in the female's uterus until spring when fertilization takes place. Twins are usually born from May through July (usually early June) in the eastern US (Christian 1956, Barbour and Davis 1969). Gestation lasts 60 days, lactation lasts 32 to 40 days and young begin to fly at four to five weeks (Kunz 1974, Kurta and Baker 1990). Only some females of this species reproduce at the end of their first year (Schowalter and Gunson 1979), but males reach sexual maturity by autumn of the first year (Christian 1956). The reproductive habits of this species are unknown in South Carolina.

**Food Habits and Foraging**

Emerging within the first hour after sunset, the flight of big brown bats to foraging areas is at a height of approximately 20 to 35 feet (6 to 10 m) and is strong and direct (Harvey et al. 2011). The flight speed of this species out in the open is 20.5 miles per hour (33 kmph), or 8 to 11 miles per hour (13 to 18 kmph) in an enclosed area (Craft et al. 1958, Patterson and Hardin 1969). Big brown bats travel an average distance of about 0.62 to 1.24 miles (1 to 2 km) to foraging areas from their day roost (Brigham 1991). This species flies for an average of one hour and 40 minutes each night, with the majority of foraging activity happening within the second hour after sunset (Kurta and Baker 1990). Each night a few foraging bouts are made, interspersed with night roosting. Some individuals may even follow the same feeding pattern on different nights, and use the same feeding ground each night (Harvey et al. 2011).

Big brown bats are known to forage in a wide variety of habitats including open areas such as fields or large gaps within forests, over water and lake edges, and foraging around lights in rural areas (Geggie and Fenton 1985, Kurta and Baker 1990, Menzel et al. 2001*b*). Females are known to use an average foraging area of 1 $mi^2$ (2.7 $km^2$) compared to 2 $mi^2$ (5 $km^2$) for males (Wilkinson and Barclay 1997). When comparing activity in National Parks, big brown bat activity was found to be lowest in fragmented rural parks and greatest in urban forest parks (J. B. Johnson et al. 2008). Additionally, within urban habitats foraging activity was found to be lowest in commercial areas and greatest in parkland and residential areas (Geggie and Fenton 1985). This species may prefer foraging among tree foliage rather than above or below the forest canopy (Schmidly 1991), but in South Carolina has been known to forage above the forest canopy (Menzel et al. 2005*b*). In relation to fire treatments in South Carolina, Loeb and Waldrop (2008) found the activity of big brown bats to be significantly higher in thinned tree stands compared to control or burned stands. According to Menzel et al. (2001), big brown bats may also prefer rural rather than urban areas, and hardwood and pine forests over agricultural fields and clear cuts in the southeast. In the same study, the average home range size was large at 7,180 acres (2906 ha). At the Savannah River Site, foraging activity appeared to be unaffected by stand age and was concentrated over lakes and ponds, grass-brush, and bottomland hardwoods (M. A. Menzel et al. 2003). In South Carolina, the activity of big brown bats has been recorded widely around Lake Jocassee and Lake Keowee, in April, July and October at 29 of the 31 sites surveyed (Webster 2013). However, the specific foraging habits of big brown bats in the state are not known.

The powerful jaw and heavy teeth of this species assists in consuming beetles, which constitutes most of their diet (Phillips 1966, Whitaker 1972, 1995, Menzel et al. 2000*b*). However, in some areas Lepidoptera are an important dietary source for big brown bats, and they also feed on Isoptera, Hemiptera, Homoptera, Hymenoptera, Diptera, Ephemeroptera, and Plecoptera (Ross 1967, Freeman 1981, Menzel et al. 2000*b*, Harvey et al. 2011). Four percent of stomach contents are made up of nonflying prey and vegetation in Indiana (Whitaker 1972). In Georgia, this species fed mostly on Coleoptera and Lepidoptera (Carter et al. 1998). Also in Georgia, females during the reproductive period may choose to forage on coleopterans over lepidopterans, dipterans, and hymenopterans based on the availability of these insects in the foraging area (Menzel et al. 2000*b*). In South Carolina, Coleoptera and Lepidoptera have been known to make up the majority of this species diet, though evidence of other insects were also found (Donahue 1998).

**Seasonal Movements**

This species is considered sedentary and their movement from summer roosts to hibernacula is less than 56 miles (90 km) (Mills et al. 1975, Neubaum et al. 2006). Big brown bats have been shown to move extensively due to their homing ability, as Reite and Davis (1966) reported that 85% returned when released about 250 miles (400 km) north of their roost, while only 6% returned when released from the south the same distance.

**Longevity and Survival**

Though few individuals actually live to a relatively old age, big brown bats are capable of living at least 20 years in the wild (Davis 1986). Survival rates are higher in adults than in juveniles (O'Shea et al. 2010, 2011). Based on banding data, the estimated mean annual survival for males is 0.70 years and for females is 0.47 years (Hitchcock et al. 1984). Hitchcock also calculated an average annual survival rate for big brown bats in Minnesota of 82% for males and 74% for females.

**Threats**

Mortality from WNS may be a potential threat for big brown bats. However, a recent study shows that this species is highly resistant to WNS. In big brown bats, the degree of infection by *Pd* may be limited to the outer epidermis during torpor, preventing lesions, evaporative water loss, and subsequent short torpor bouts thought to prematurely burn fat reserves during hibernation (Frank et al. 2014).

Disturbance or destruction of natural and artificial roost structures may be a potential threat to this species, and many forms of habitat alterations can also cause increased predation by natural predators (Bunch et al. 2015*b*).

Deforestation of oak (*Quercus* species) from Sudden Oak Death (SOD) disease caused by the plant pathogen *Phytophthora ramorum* may pose a threat to habitats critical to forest-dwelling bats. Though it has not been found in a natural setting to date, this disease was recently detected on nursery stock (Bunch et al. 2015*b*).

Pesticide poisoning, especially by organochlorines and anticholinestrase, is a threat to this species because it has been shown to cause population declines in insectivorous bats (Geluso et al. 1976, Reidinger 1976, Brady et al. 1982). Pesticides can also alter behavior, cause mortality, and be transferred to nursing young (Clark 1981, 1986, Henny et al. 1982).

Wind energy may threaten big brown bats as well, as fatalities of this species at wind turbines have been documented (Gruver 2002, Arnett et al. 2008). Big brown bats have been one of six bat species killed at a wind power developments at Buffalo Ridge, Minnesota and Buffalo Mountain Windfarm, Tennessee (Johnson et al. 2003, Fiedler 2004). However, the percentages of fatalities are still relatively low compared to migratory tree bats. For example, big brown bats comprised 1.9% of the total fatalities in a review of bat mortality at wind energy developments in the US by Johnson (2005), and were 3% of the total bat fatalities found by Arnett et al. (2009) at the Casselman Wind Project in south-central Pennsylvania. No wind turbines have been placed in South Carolina to date, however, Clemson University is constructing a test facility for turbines at the coast (Bunch et al. 2015*b*).

Small numbers of deadly collisions with towers in Florida have been recorded for this species (Crawford and Baker 1981). However, the level of impact from tower mortalities on local or range wide populations remains unclear.

Global climate change is a potential threat to big brown bats because it may make southern hibernation sites unsuitable due to increased temperatures (Bunch et al. 2015*b*).

**Conservation Measures**
Bat exclusion, not extermination, is the most effective and humane way to remove bats from buildings. Sealing out bats and/or adding more light to the roost of a colony are more effective alternatives than use of pesticides for control purposes (Laidlaw and Fenton 1971, Barclay et al. 1980). To minimize negative impacts to big brown bats, eviction from buildings should include appropriately timed exclusion methods. To avoid the maternity period, bats should not be evicted from May through July. Alternatively, populations at the roost area may be decreased by 41 to 96% if lights are introduced to the area (Laidlaw and Fenton 1971). Measures should be taken to provide species-specific alternate roost structures before eviction, and typical bat boxes are a reasonable alternative for big brown bats.

Other habitat protection and management recommendations from Bunch et al. (2015*b*) include working to prevent or reduce disturbance to natural and artificial roost structures, as well as to maternity colonies and hibernacula through gating, warning or interpretive signs, prevention of trails or roads to these sites, and other protective measures; retain and recruit cypress-gum swamp forests with large cavity trees; designate no-cut buffer zones around known roosts; provide forested corridors between harvested units; and protect foraging areas and migration corridors, which could be done through landowner incentive programs, conservation easements, lease agreements, or purchases. Other measures may include providing, protecting, and maintaining large diameter roost trees, large snags, decadent trees, hollow trees, and roost structures, especially near water or riparian areas; attempting to create or maintain patches of structurally diverse forest in order to provide a wide variety of suitable roosting and maternity sites; minimizing large-scale pesticide use whenever possible; and protecting habitat above or around maternity roosts and known foraging areas from pesticides.

Priority survey and research recommendations from Bunch et al. (2015*b*) include conducting seasonal surveys at caves and mines being considered for closure; and evaluating roost and appropriate food (insects high in polyunsaturated fats) availability, as well as roost temperatures, and compare these factors with winter survival. Further research is greatly needed to identify the best placement of wind turbines, as well as strategies that would minimize impacts to bats (Ellison 2012). The SCDNR Heritage Trust tracks high priority species including the big brown bat, and researchers are requested to submit bat data and occurrence records to their database.

Education and outreach goals recommended by Bunch et al. (2015*b*) include working to create general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans.

# Brazilian Free-tailed Bat (*Tadarida brasiliensis*)

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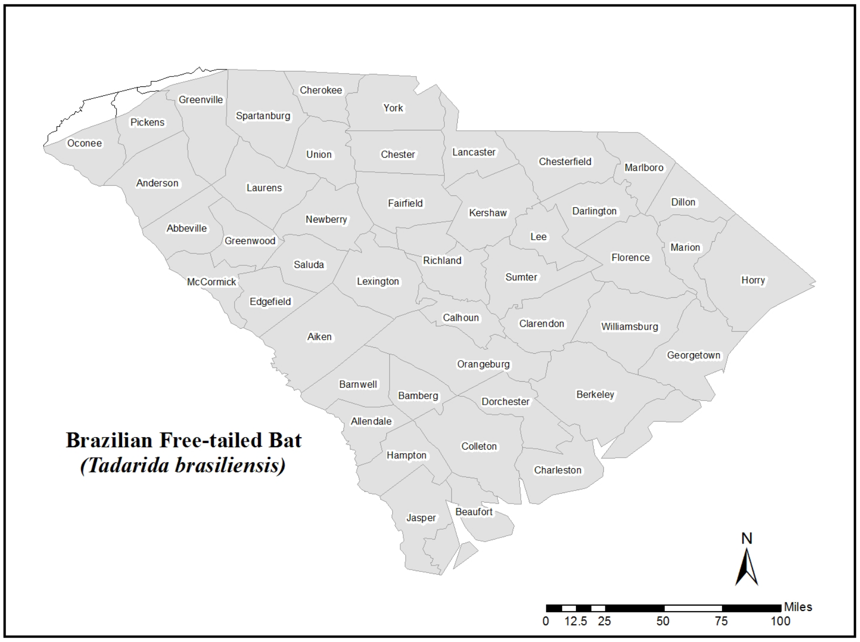
**Description**
Brazilian free-tailed bats differ from all South Carolina bats in that they are a member of the Molossidae or "free-tailed bat" family and have a characteristic mouse-like tail extending past the membrane stretched between the hind legs. This species forms the largest concentrations of mammals in the world. Each year 100 million bats arrive in central Texas to raise their young, and the largest known bat colony in the world holds 20 million of those at Bracken Cave near San Antonio during the summer (Harvey et al. 2011). The impressive number of insects consumed by these colonies provides a substantial pest control service to humans. In an eight county region in south-central Texas, the value of pest control provided by Brazilian free-tailed bats was estimated at $741,000 per year for cotton producers (Cleveland et al. 2006). The Mexican free-tailed bat, a subspecies of the Brazilian free-tailed bat, provides a total annual cotton pest-suppression service of $11.67 million in the southwestern US and northern Mexico (López-Hoffman et al. 2014). Unfortunately, wind energy development may pose a threat to this species. Piorkowski and O'Connell (2010) showed a steady rate of collision mortality and from the seven bat species killed by wind turbines, 85% of all fatalities were Brazilian free-tailed bats.

**Identification**
The Brazilian free-tailed bat is a small to medium sized bat weighing 0.4 to 0.5 ounces (11 to 15 gr) and has a wingspan of 11 to 14 inches (29 to 35 cm) (Harvey et al. 2011). The upper lip is strongly wrinkled, the blackish ears are short and nearly square, and the short, velvety pelage is dark brown to dark gray. However, the pelage may bleach to various shades of reddish brown depending on the concentration of ammonia found at their roost site (Tuttle 1994). The wings are long and narrow and the membranes are blackish. Short, powerful hind legs and large feet give this species excellent climbing abilities, and long hairs protruding from the toes are thought to judge flight speed and turbulence. Brazilian free-tailed bats are the fastest of all North American bats, flying at speeds of up to 40 to 60 miles per hour (65 to 95 kmph) (Whitaker and Hamilton 1998).

**Taxonomy**
Currently there are nine recognized subspecies of the Brazilian free-tailed bat (Wilson and Reeder 2005). *Tadarida brasiliensis cynocephala*, also referred to as Le Conte's free-tailed bat, is the only subspecies found in South Carolina (M. A. Menzel et al. 2003).

**Distribution**
This species is one of the most widely distributed mammals in the Western Hemisphere (Wilkins 1989). It is found southward from the southern US through Mexico and Central America, and into large areas of South America. It is also present on islands of the Caribbean (Harvey et al. 2011).




grassland, savanna, shrubland, suburban and urban habitats (NatureServe 2017).

In the past, Brazilian free-tailed bats were mainly distributed throughout the state south of the Piedmont region, but in recent years they have been commonly recorded in the upper Piedmont.

**Population Status**

Common through most of its range, the Brazilian free-tailed bat is ranked as Globally Secure (G5), Nationally Secure (N5) and Subnationally unranked (SNR) (NatureServe 2017). However, it is currently ranked as Subnationally Apparently Secure (S4S5) by the SCDNR Heritage Trust (see Table 2). It is currently classified as Least Concern (LC) on the IUCN Red List (Barquez et al. 2008). This species is also considered locally common, and not a Priority species in the South Carolina 2015 SWAP (SCDNR 2015).

**General Habitat**

From pine-oak forests from sea level to 9,000 feet (2,743 m) in elevation, to pinion-juniper woodlands and desert ecosystems, this species is found in a wide variety of habitats throughout its range (Bat Conservation International 2015). They are also found in

**Roosts and Roosting Behavior**

Summer and winter roosting habits for this species tend to be very similar. In the southeast, natural roosts for this species used to be hollows of mangroves and cypress trees (Jennings 1958). Today they are found mainly in human-made structures, day roosting in tight colonies in undisturbed buildings and attics at least 9.8 feet (3 m) above the ground in order to attain flight through free fall when departing from the roost (Jennings 1958, Barbour and Davis 1969). They may also be found under bridges, in tunnels and hollow trees (Lowery 1974, Tuttle 1994). Brazilian free-tailed bats are thought to feed all night and therefore rarely use night roosts (Whitaker and Hamilton 1998). However, specific roosting habits for this species in South Carolina are unknown.

During spring and summer, sexes generally roost in separate locations. Males form groups from dozens up to 100,000 individuals at elevations over 9,000 feet (2,740 m), while females usually form maternity colonies below 5,000 feet (1520 m) in warm, dry areas of the species' northern range (Freeman and Wunder 1988, Tuttle 1994). The number of adult females in maternity colonies ranges from a minimum of 20,000 to 20 million found in Bracken Cave near San Antonio, Texas (Caire et al. 1989, NatureServe 2015). However, southeastern colonies are usually composed of less than 50,000 individuals (M. A. Menzel et al. 2003), and colonies of Le Conte's bat (*T. b. cynocephala*) don't generally exceed several thousand individuals in Florida (Bain 1981). Females do not roost with their offspring, but instead deposit them in a crèche and visit them several times a day to nurse. Large maternity colonies roost in limestone caves, abandoned mines, buildings, and bridges, while smaller colonies roost in hollow trees (Wilkins 1989, Bat Conservation International 2015). Females tend to return to natal caves to breed (Caire et al. 1989). Sites with relatively hot temperatures are often chosen, and large numbers of individuals generate enormous amounts of heat essential for the rapid growth of young bats (Kunz and Robson 1995). The guano from these large colonies, along with fallen bats, is consumed by dermestids on the cave floor. The waste from these carpet beetles, when combined with water vapor, can create enormous concentrations of ammonia lethal to humans. Brazilian free-tailed bats survive this by lowering their metabolic rate and accumulating carbon dioxide in their blood and respiratory mucus, which neutralizes the ammonia (Tuttle 1994). The copious amounts of guano associated with this species tend to accumulate in commercially significant amounts and have been mined for fertilizer and gunpowder manufacturing (Hutchinson 1950).

During winter in the western US, this species is not a true hibernator and migrates south for the winter, but in the southeast is apparently nonmigratory and may enter torpor for short periods during extremely cold weather (Barbour and Davis 1969, Lowery 1974, Wilkins 1989). Little is known about the roosting habits of Brazilian free-tailed bats in South Carolina during winter, though they likely overwinter in buildings. In order to keep warm, the clustering behavior of *T. b. cynocephala* increases bat cluster compactness as the temperature decreases (Pagels 1975). Roosting groups are probably much smaller during winter than those during summer. For example, in Florida about 10,000 bats summered in a house in Gainesville but by winter only a few hundred remained (Whitaker and Hamilton 1998).

**Reproduction**

Unlike many bat species, female Brazilian free-tailed bats do not store sperm for a considerable amount of time over winter. Mating occurs in mid-Feb to late March (Wilkins 1989), and shortly thereafter the females migrate to maternity roosts. Gestation lasts from 77 to 100 days (Feldhamer et al. 2003), and typically one pup is born from late May to late June (or as late as early August) (Sherman 1937, Barbour and Davis 1969, Wilkins 1989). The fat content of the milk fed to the pups is one of the highest reported for bats at over 28% (Sosnicki 2012), and thus their growth is relatively quick. Lactation lasts about 45 days, and young begin to fly and forage at five to six weeks (Kunz and Robson 1995). Amazingly, a female can find her young in a colony of thousands of pups by recognizing the calls and scent of her own pup (McCracken and Gustin 2010). Females of this species become sexually mature around nine months, while males are not sexually mature until their second year (Sherman 1937).

**Food Habits and Foraging**

Emerging around sunset (Bailey 1951), Brazilian free-tailed bats can cover an area of 154 miles squared (400 km$^2$) and are thought to feed all night (Lee and McCracken 2005). The numbers of this species are often so great that they can be detected by airport and weather radar, and the sound of their wings have been compared to that of a roaring river as they fly out from their roosting colonies. The Brazilian free-tailed bat has the highest recorded flight altitude among bats at over 10,826 feet (3,300 m) and may fly up to 150 miles (241 km) to reach foraging areas (Williams et al. 1973). They typically travel at a height of approximately 50 feet (15 m) to reach foraging areas, and feed within 50 miles (80 km) from the day roost (Whitaker et al. 1980). This species is highly adapted to an aerial lifestyle involving fast, direct flight, and can fly up to 40 to 60 miles per hour (65 to 95 kmph) (Whitaker and Hamilton 1998). With a high wing aspect ratio and wing loading, they are only moderately maneuverable (Vaughan 1966) and hunt in open spaces, usually well above the trees of woodlands and forests. About 60% of its time is spent foraging while cruising, 12% spent foraging, and the rest spent cruising and resting (Caire et al. 1984).

As an opportunistic insectivore, the diet of this species varies based on geographical range but includes Lepidoptera, Coleoptera, Diptera, Hymenoptera, Homoptera, Heteroptera, Neuroptera, and Trichoptera (Whitaker 1995, Whitaker and Hamilton 1998, Schwartz and Schwartz 2001). For example, Ross (1961) and Storer (1926) found 90% of their diet consists of moths from the Gelechiidae family between 5 and 9 mm long. During feeding bouts, a population of this species in Texas was found to eat coleopterans and lygaeid bugs in the evening and moths in the morning (Whitaker et al. 1996). It is estimated that the 100 million Brazilian free-tailed bats in central Texas caves significantly impact local populations of insects and agricultural pests, such as cotton bollworm moths and army cutworm moths, by consuming 1,000 tons of insects nightly (McCracken and Westbrook 2002). Not much is known about the diet of Brazilian free-tailed bats in South Carolina, however.

**Seasonal Movements**

Some subspecies of the Brazilian free-tailed bat in the Great Plains, Texas, and the southwest are known to migrate great distances to Mexico, though some males in the Great Plains have been known to remain in their winter range during the summer instead of migrating north in the spring (Glass 1982). However, in South Carolina this species is resident all year and flying individuals have been shot in the state in January (Whitaker and Hamilton 1998).

**Longevity and Survival**

The longest-lived individual of this species in the wild has been recorded at eight years, while that of a captive individual was recorded at 12 years (Weigl 2005). Using a lifespan of 15 years, the predicted survival rates for both sexes are around 70 to 80% (Davis et al. 1962).

**Threats**

The Brazilian free-tailed bat is especially vulnerable to habitat destruction and human disturbance due to its tendency to roost in large numbers at relatively few roost sites (Lowery 1974, Humphrey 1992). Population declines of the Brazilian free-tailed bat have been reported over the last 50-100 years in the US, potentially due to the destruction and disturbance of large roosting colonies such as maternity sites, as well as direct or indirect poisoning by pesticides and heavy metals (McCracken 1986, Gannon et al. 2005). Pesticides may alter behavior, cause mortality, and be transferred to nursing young (Clark 1981, 1986, Henny et al. 1982). Because this species consumes large amounts of crop pests, they may have an increased risk of contamination from the accumulation of organochlorine pesticides in their body fat. During migration when fat is metabolized, exposure to these pesticides is increased and can be lethal (Bennett and Monte 2007). Young bats are particularly susceptible to pesticides through their mother's milk and post-weaning diet (Clark et al. 1975).

Dynamiting, burning, and guano mining have also caused complete loss of some maternity roosts in the US and Mexico. Housing development, vandalism, wind turbines, pollution, and climate change may also threaten roots with the highest risk to bat populations that reside in Bracken Cave, Congress Avenue Bridge, and Davis Cave in Texas (Svancara et al. 2014).

Wind energy development is a major threat, as large numbers of Brazilian free-tailed bats have been killed from wind turbine collisions. Piorkowski and O'Connell (2010) showed a steady rate of collision mortality of this species at the Oklahoma Wind Energy Center, and reported that of the seven bat species killed by wind turbines, 85% of all bat fatalities were Brazilian free-tailed bats. No wind turbines have been placed in South Carolina to date, however, Clemson University is constructing a test facility for turbines at the coast (Bunch et al. 2015*b*).

**Conservation Measures**

Bat exclusion, not extermination, is the most effective and humane way to remove bats from buildings. Sealing out bats and/or adding more light to the roost of a colony are more effective alternatives than use of pesticides for control purposes (Laidlaw and Fenton 1971, Barclay et al. 1980). To minimize negative impacts to Brazilian free-tailed bats, eviction from buildings should include appropriately timed exclusion methods. Alternatively, populations at the roost area may be decreased by 41 to 96% if lights are introduced to the area (Laidlaw and Fenton 1971). To avoid the maternity period, bats should not be evicted from May through July.

Other habitat protection and management recommendations from Bunch et al. (2015*b*) include working to prevent or reduce disturbance to natural and artificial roost structures, as well as to maternity colonies and hibernacula through gating, warning or interpretive signs, prevention of trails or roads to these sites, and other protective measures; retain and recruit cypress-gum swamp forests with large cavity trees; designate no-cut buffer zones around known roosts; provide forested corridors between harvested units; and protect foraging areas and migration corridors, which could be done through landowner incentive programs, conservation easements, lease agreements, or purchases. Other measures may include providing, protecting, and maintaining large diameter roost trees, large snags, decadent trees, hollow trees, and roost structures, especially near water or riparian areas; attempting to create or maintain patches of structurally diverse forest in order to provide a wide variety of suitable roosting and maternity sites; minimizing large-scale pesticide use whenever possible; and protecting habitat above or around maternity roosts and known foraging areas from pesticides.

Priority survey and research recommendations from Bunch et al. (2015*b*) include conducting seasonal surveys at caves and mines being considered for closure; evaluating roost and appropriate food (insects high in polyunsaturated fats) availability, as well as roost temperatures, and compare these factors with winter survival. Further research is greatly needed to identify the best placement of wind turbines, as well as strategies that would minimize impacts to bats (Ellison 2012). Researchers are requested to collect and record bat data, but the SCDNR Heritage Trust does not track this species in its database.

Education and outreach goals recommended by Bunch et al. (2015*b*) include working to create general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans.

# Eastern Red Bat (*Lasiurus borealis*)

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**Description**

The eastern red bat is distinctive in its remarkable bright red to rusty-red pelage, and is known to be the most abundant foliage roosting bat in North America. Their unique color is a form of camouflage that mimics dead leaves or pinecones as they hang, wrapped by their furry tail membrane in the foliage of trees. Unusual in bat species, males and females seem to differ in color, with males being brighter red than females. However, this characteristic might be linked more to body size than sex (Davis and Castleberry 2010). Eastern red bats are a solitary foliage roosting species and do not hibernate in caves. Instead their thick insulative skin, heavily furred uropatagium, and short, rounded ears assist in minimizing heat loss while hibernating in trees. Unfortunately, the eastern red bat is one of the most frequently reported bat species found dead at wind turbine facilities in North America (Ellison 2012).

**Identification**

This species is a medium sized bat that weighs 0.3 to 0.5 ounces (9 to15 gr) and has a wingspan of 11 to 13 inches (28 to 33 cm) (Harvey et al. 2011). The brick red fur is soft and fluffy with some hairs tipped with white (more so in females and juveniles), and a buffy white patch on the front of the shoulders. The ears are broad, rounded and low on the head, and the tragus is triangular. The wings of eastern red bats are long and pointed, and the dorsal side of the uropatagium is covered in thick fur. Their skull is short, broad and heavily constructed.

**Taxonomy**

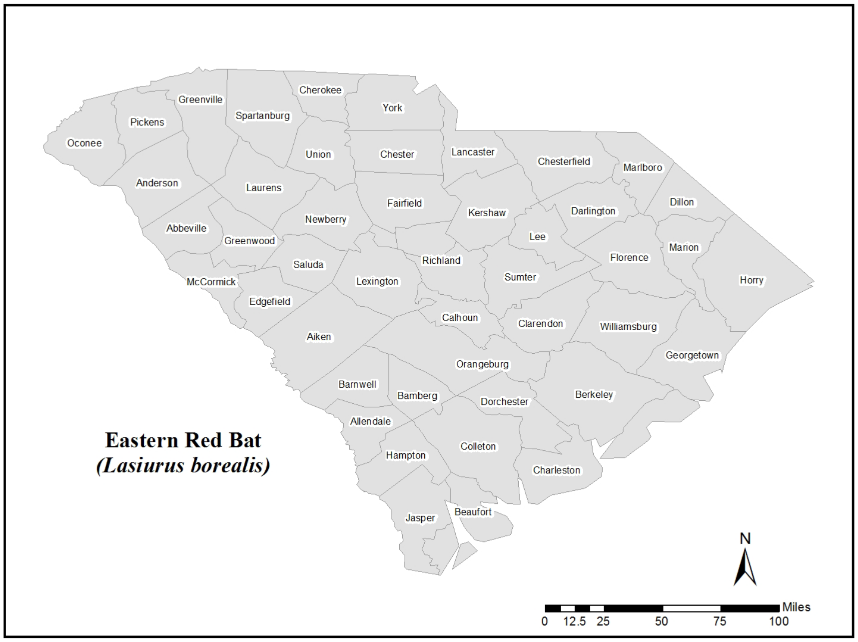
Though a number of subspecies were once recognized (Shump and Shump 1982*b*), the eastern red bat is now considered monotypic (Wilson and Reeder 2005).

**Distribution**

Eastern red bats are distributed throughout southern Canada, into the eastern US (but not the Florida peninsula), and southward into northeastern Mexico, Argentina and Chile. In the US, their range extends west to the Midwestern and east-central states (Shump and Shump 1982*b*, Harvey et al. 2011). In the winter, this species migrates to southern states and is found from southern Illinois and southern Indiana south (Whitaker and Hamilton 1998). In South Carolina, eastern red bats are common statewide and found in all four physiographic provinces (M. A. Menzel et al. 2003).

**Population Status**

Common and abundant through most of its range, the eastern red bat G has a rounded rank of lobally Vulnerable (G3G4), Nationally Secure (N5) and Subnationally unranked (SNR) (NatureServe 2017). However, it is currently ranked as Subnationally Apparently Secure (S4S5) by the SCDNR Heritage Trust (see Table 2). It is currently classified as Least Concern (LC) on the IUCN Red List (Arroyo-Cabrales et al.




**Eastern Red Bat**
***(Lasiurus borealis)***

2008*a*). This species is considered locally common, but is listed as a Highest Priority species in the South Carolina 2015 SWAP (SCDNR 2015) due to severe WNS-related mortality occurring in other bat species, and the fact that *P.d.* has been detected on eastern red bats but no diagnostic sign of WNS has been documented.

**General Habitat**

Occurs throughout forested habitat of the eastern US, and is partial to elm trees (*Ulmus* species), wooded hedgerows, and large shade trees in urban areas such as those found in city parks (Mager and Nelson 2001). In South Carolina, habitat types used in the home range of five eastern red bats tracked at the Savannah River Site included 55% bottomland hardwoods, 40% pine stands, and 5% upland hardwoods (Carter 1998). Additionally, sparse vegetation was found to be the best predictor of habitat use by eastern red bats (Loeb and O'Keefe 2006).

**Roosts and Roosting Behavior**

Eastern red bats are a solitary roosting species found mainly in trees and shrubs, as well as near or on the ground (Hall and Kelson 1959), as well as in Spanish moss (*Tillandsia usneoides*) (Constantine 1958). Day roosts are often in areas of edge habitat adjacent to open fields, streams, and in urban areas (Shump and Shump 1982*b*).

During summer, eastern red bats are usually found roosting on leaf petioles and small branches in the tops of deciduous trees (Barbour and Davis 1969), though they may also be found in caves (Myers 1960), woodpecker cavities (Fassler 1975), leaf litter (Moorman et al. 1999), dense grass, and shingles of houses (Mager and Nelson 2001). Mager and Nelson (2001) found 89 % of roosts were in foliage or the trunks of deciduous trees greater than 18 inches (45 cm) dbh. Though eastern red bats are often found roosting in deciduous trees, Elmore et al. (2004) found that within thinned pine stands of intensively managed pine landscapes in Mississippi, 70% of their day roosts were found in 16 species of hardwood trees and 30% in loblolly pines. Also, preferred roosts were located within denser subcanopy and higher basal area, but specific tree characteristics were not as important as those at the stand-level. Nonreproductive eastern red bats in the southern Appalachian Mountains also did not select roosts based on tree or microhabitat characteristics and used a wide range of stand conditions and ages (O'Keefe et al. 2009). At the Savannah River Site in South Carolina, roosts were found in 23 total tree species, and sweetgum (*Liquidambar styraciflua*) and red maple (*Acer rubrum*) were used most (Menzel et al. 2000*a*). In the same study, compared to random plots, roost trees were found in stands with larger basal areas, higher and denser overstory, and more diverse overstory and understory. Roost sites were switched often, with an average of 1.2 nights spent at each tree (Menzel et al. 1998). Frequent roost switching may be a response to changing microclimate conditions at different trees (Kunz 1982*b*). The mean maximum distance between locations for three eastern red bats in the southern Appalachian Mountains was 1,476 ± 298 feet with a range of 6.8 to 2,744 feet (450 ± 91 m; range 2.1–836.5 m) (O'Keefe 2009). Though this species has low roost site fidelity, they are known to have high site fidelity and thus commonly roost within the same general area (Hutchinson 1998, Mager and Nelson 2001). Eastern red bats may forage in close association with each other during summer, and different individuals often use roost sites on different days (Constantine 1966, Downes 1964). In Illinois, large trees in urban areas were found to be extremely important roosting sites for eastern red bats in an otherwise fragmented landscape (Mager and Nelson 2001). In a study in Iowa, McClure (1942) found roosts in dense shade and cover on the south side of trees at a height of between 3.6 to 10.2 feet (1.1 to 3.1 m) to be preferred. However, the majority of roosts found by Mager and Nelson (2001) in central Illinois were located on the north or east side of trees at a height greater than 16 feet (5 m). In South Carolina, female eastern red bats have been found to select trees on north and northwest facing slopes (Leput 2004), and roosts in Georgia and South Carolina forests were found at an average height of 50 feet (15.3 m) (Menzel et al. 1998).

Females roost separately with young in tree foliage instead of in colonies. When found in family clusters, the preferred height of the roost site increased from 10.2 to 20.3 feet (3.1 to 6.2 m) (McClure 1942). During summer, females have higher temperature demands for birthing and nursery conditions, and seem to be restricted to lower elevations associated with higher temperatures in the eastern US (Ford et al. 2002). As family groups broke up, young continued to occupy higher roosts compared to adults who appeared to have no preference (Constantine 1966).

In the fall in the South Carolina, eastern red bats have been seen flying out of leaf litter ahead of prescribed burns (Moorman et al. 1999).

During winter, eastern red bats are commonly found in leaf clusters and tree branches, though some hibernate in old squirrel nests, leaf litter, and Spanish moss (Constantine 1958, Barbour and Davis 1969, Saugey et al. 1989). Northern populations migrate south for the winter, but most eastern red bats in South Carolina are considered resident. However, the winter habits of eastern red bats are not well known in the state. This species may become torpid at temperatures below 69°F (20°C), and survives subfreezing temperatures by maintaining body temperature just above the critical limit of 23°F (-5°C) (Reite and Davis 1966). Eastern red bats were found actively feeding throughout the year in southeastern Virginia and northeastern North Carolina at temperatures above 48°F (9°C) (Padgett and Rose 1991, Whitaker et al. 1997). Similar to bats considered true hibernators, eastern red bats may lose 25% of their pre-hibernation body weight by spring (Fenton 1985). According to Whitaker and Hamilton (1998), males and females have separate winter and summer ranges and migrate at different times. However, in California males and females have been found to winter together (Williams and Findley 1979).

**Reproduction**
Copulation may be initiated in flight (Stuewer 1948), and mating occurs between August and September (Glass 1966, Whitaker and

Hamilton 1998). Sperm is stored in the female's uterus until spring when fertilization takes place. The mother gives birth from one to five young (average of two) in late May to mid June or July, and has four mammary glands instead of two found in most bats (Shump and Shump 1982*b*). Gestation lasts 80 to 90 days (Jackson 1961), lactation lasts 38 days (Kunz 1971), and young are weaned between four to six weeks and begin to fly between three to six weeks (Hamilton 1943, Jackson 1961, Barbour and Davis 1969). Males and females of this species mature relatively early compared to many South Carolina bat species as they are sexually mature by their first autumn (Cryan et al. 2012).

**Food Habits and Foraging**

Eastern red bats usually begin to forage about one to two hours after sunset, with the most active foraging periods corresponding to the initial, and later the increased, nocturnal activity of insects (Kunz 1973), though nursing adult females may feed all night. With a high aspect ratio and high wing loading, this species is only moderately maneuverable and can fly relatively fast (Shump and Shump 1982*b*). Eastern red bats may travel between 1,600 to 3,000 feet (500 to 900 m) from day roosts to feeding sites (Jackson 1961). The distance traveled while foraging is around 0.25 to 3.2 miles (0.4 to 5.5 km), and the foraging speed of this species is around 15 miles per hour (24 kmph) on average (Naughton 2012).

Eastern red bats may forage at or above treetop level (Schmidly 1991), over water such as lakes or streams, habitat edges (Furlonger et al. 1987), open habitats, in cypress stands, and around lights where they may land on light poles to catch moths (Barbour and Davis 1969, Hickey and Fenton 1990). However, the activity of this species did not differ above, within, or below the forest canopy in a South Carolina study by Menzel et al. (2005) despite being considered a clutter-adapted species. In relation to fire treatments in South Carolina, Loeb and Waldrop (2008) found the activity of eastern red bats to be significantly higher in thinned tree stands compared to control or burned stands. At the Savannah River Site, Carter (1998) found the average home range for this species to be 1,119 acres (453 ha), and the habitat types within the home range were 55% bottomland hardwoods, 40% pine stands, and 5% upland hardwoods. In the Coastal Plain of South Carolina, foraging activity was mostly over riparian areas, wetlands, and bottomlands in both cluttered and uncluttered habitats (Menzel et al. 2005*b*, *a*). The activity of eastern red bats has been recorded widely around Lake Jocassee and Lake Keowee in the state, and was found in 30 of the 31 sites surveyed in April, July, and October (Webster 2013).

Eastern red bats have been found to consume Coleoptera, Diptera, Hymenoptera, Homoptera, Lepidoptera, and Orthoptera, which includes specific insects such as ground-dwelling crickets, cicadas, and grain moths (Connor 1971, Hamilton 1943, Jackson 1961, Lewis 1940). In Indiana, the diet of this species consisted of 26.2% moths and 28.1% beetles, with the rest including June bugs, ants, and leafhoppers (Whitaker and Hamilton 1998). In early summer in South Carolina, eastern red bats generally feed on Coleoptera and Hemiptera, and as the summer continues may add Lepidoptera, Homoptera, and Hymenoptera to their diet (Carter 1998, Donahue 1998, Carter et al. 2004). During winter in North Carolina, this species is seen actively feeding on moths and flies, generally at temperatures above 48°F (9°C) (Padgett and Rose 1991, Whitaker et al. 1997). On average, Hickey et al. (1996) found that eastern red bats in Ontario attack insects every 30 seconds and are successful 40% of the time.

**Seasonal Movements**
Considered highly migratory, this species tends to migrate in groups despite normally being a solitary roosting species (LaVal and LaVal 1979, Shump and Shump 1982*b*). Eastern red bats migrate from northern states to the southern US to hibernate (M. A. Menzel et al. 2003). However, in South Carolina eastern red bats are considered year round residents, and their numbers increase in late fall and winter as winter migrants arrive.

**Longevity and Survival**
The maximum life span of the eastern red bat has been estimated at 12 years (Saunders 1988).

**Threats**
Populations of this species may have substantially declined in the last century, as there are reports of much larger flocks seen in the 1800s (Bat Conservation International 2015). More recently, a study in Michigan by Winhold (2008) found that the number of eastern red bats captured had decreased between 52 to 85% in a 12 to 26 year period.

At wind turbine facilities in North America, the eastern red bat is one of the most frequently found dead, and one of the top species recorded with the most bat fatalities (Ellison 2012). For example, Fiedler (2004) found that 61.3% of the bat fatalities at a wind farm in eastern Tennessee were eastern red bats, where the overall bat mortality rate for the site was 20.8 bats/turbine/year. Because the eastern red bat is one of three migratory tree bats that compose the majority of wind turbine fatalities, it has been suggested that seasonality and migration patterns make them more vulnerable to collisions (Cryan 2011). No wind turbines have been placed in South Carolina to date, however, Clemson University is constructing a test facility for turbines at the coast (Bunch et al. 2015*b*).

Large buildings also pose a collision threat to eastern red bats. Timm (1989) reported that 50 individuals struck the large glass windows of one convention center in Chicago over an 8-year period. Forty-eight of those individuals were collected during the fall, suggesting that the bats hit the building during migration. Small numbers of deadly collisions with towers in Florida have also been recorded (Crawford and Baker 1981).

WNS has the potential to be a threat as it has been detected on eastern red bats, but they have not yet shown diagnostic sign of the disease (White-nose Syndrome.org 2015).

Prescribed burning in the fall may also pose a threat to eastern red bats since they are found hibernating in leaf litter in South Carolina during this time (Moorman et al. 1999).

Habitat and roost site loss due to development and removal of palm fronds are other potential threats for this species (Bunch et al. 2015*c*). The harvesting of Spanish moss may still be a threat in some areas, but the development of synthetic materials replacing the need for Spanish moss may have reduced this threat (Trani et al. 2007). Additionally, foraging habitat may be reduced by increased urbanization, loss of riparian habitat, and grazing. Many of these forms of habitat alterations can also cause increased predation by natural predators. Also, natural causes such as hurricanes may also create loss of habitat as well as direct mortality (Bunch et al. 2015*c*).

Pesticide poisoning, especially by organochlorines and anticholinestrase, is a threat to this species because it has been shown to cause population declines in insectivorous bats (Geluso et al. 1976, Reidinger 1976, Brady et al. 1982). Pesticides can also alter behavior, cause mortality, and be transferred to nursing young (Clark 1981, 1986, Henny et al. 1982).

**Conservation Measures**

Wind turbines are a relatively new threat, and thus very little research has been conducted on how to minimize the dangers of turbines to bats. What is known is that the new larger, taller turbines have decreased mortality in birds but actually increased bat fatalities (Barclay et al. 2007), and that facilities built on ridge tops appear to have the highest bat fatalities (Johnson and Erickson 2008). Research is greatly needed to identify the best placement of turbines, as well as strategies that would minimize impacts to bats (Ellison 2012). Wind turbine management recommendations from Bunch et al. (2015*b*) include working with wind energy development companies to mitigate the impacts of wind turbines, such as increasing the cut-in speed of turbines to reduce mortalities; and establishing timing and location of potential wind-energy conflicts through pre-construction surveys and determine potential mitigation measures to reduce mortality to eastern red bats. Also, using flashing lights instead of constant lights on towers, which is now regarded as acceptable by the FAA, can reduce bat mortality (Bunch et al. 2015*a*).

Other habitat protection and management recommendations from Bunch et al. (2015*c*) include working to minimize bat mortality during prescribed burn activities by burning in the spring or summer; advise forestry professionals to conduct controlled burns when minimum night temperatures are > 39°F (4°C) and temperatures at the time of ignition are > 50°F (10°C); retain and encourage retention of Spanish moss and old palm fronds on public lands; and timber management in the Piedmont region that includes pine thinning or controlled burns may benefit this species by creating more open forest areas. Other measures may include working to maintain hedgerow habitats along crop borders; retain large trees in urban areas; minimize or carefully consider large-scale pesticide use whenever possible; and protect habitat above or around maternity roosts and known foraging areas from pesticides.

Priority survey and research recommendations from Bunch et al. (2015*c*) include conducting further research to better understand winter roost site and habitat requirements of eastern red bats; gather migration information for eastern red bats; determine the extent and seasonality of off-shore commuting and foraging to assess vulnerability of eastern red bats to off-shore wind development; and determine the vulnerability of eastern red bats, especially during fall migration, to coastal wind energy development. Other recommendations might include research to better understand population status, summer roost sites, and behavior of this species. The SCDNR Heritage Trust tracks high priority species including the eastern red bat, and researchers are requested to submit bat data and occurrence records to their database.

Education and outreach goals recommended by Bunch et al. (2015*c*) include creating general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans; and discourage the practice of removing roosting habitat such as old palm fronds and large amounts of Spanish moss from trees.

# Eastern Small-footed Bat (*Myotis leibii*)



## Description

The eastern small-footed bat is the smallest bat in South Carolina. It is also one of the smallest and rarest bats in North America, despite having a wide distribution in the northeast. Most small rodents of this size only live around 1.5 years, but the eastern small-footed bat may live eight times longer. This species is known for its ability to tolerate colder temperatures than most bats, and it hibernates for a relatively shorter period during winter. Its slow, erratic flight is characteristic enough to identify this bat in the field. Unfortunately the eastern small-footed bat is extremely susceptible to WNS, and according to Alves et al. (2014), an expected relative population reduction is estimated to be 71.2% in an intermediate population-reduction scenario (compared to a pessimistic scenario at 96.6%, and an optimistic scenario at 29.3%). An eastern small-footed bat was first discovered suffering from WNS in South Carolina at Table Rock State Park in 2013.

## Identification

The eastern small-footed bat weighs 0.01 ounce (3 to 4 grams) and has a wingspan of 8 to 10 inches (21 to 25 cm) (Harvey et al. 2011). This species is a small brown bat with a black mask, black ears, and distinctively small feet measuring only 0.2 to 0.3 inches (6 to 8 mm). The pelage is black at the root with glossy brown on the tips, and is dark on the back and whitish to buff on the belly. The wing and tail membranes, as well as the muzzle, are a dark chocolate color. This species has short, broad wings with rounded wingtips.

## Taxonomy

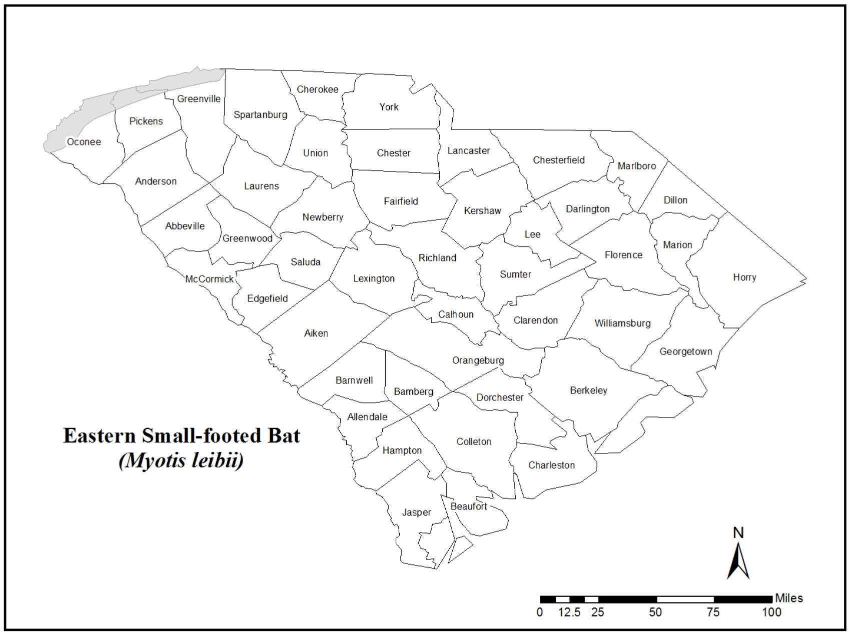
The eastern small-footed bat is considered monotypic (Wilson and Reeder 2005).

## Distribution

This species is distributed from eastern Canada and New England southwest to southeastern Oklahoma, Arkansas, and southeast to northern Alabama, northern Georgia, and northwestern South Carolina. In South Carolina, eastern small-footed bats are limited to the extreme northern portion of the Blue Ridge region (M. A. Menzel et al. 2003).

## Population Status

Considered uncommon through most of its range, the eastern small-footed bat is ranked as Globally Apparently Secure (G4), a rounded rank of Nationally Vulnerable (N3N4), and is Subnationally ranked as Critically Imperiled (S1) (NatureServe 2017). It is currently classified as Least Concern (LC) on the IUCN Red List (Arroyo-Cabrales and Álvarez-Castañeda 2008*a*). This species has never been regarded as abundant anywhere, and population trends are largely unknown. This may be in part because they're overlooked in cave surveys due to solitary roosting at inconspicuous sites (Krutzsch 1966, Dunn and Hall 1989). In South Carolina the eastern small-footed bat is listed as a Highest Priority species in the South Carolina 2015 SWAP, and is designated as "in need of management" which equates to state




threatened (SCDNR 2015). In October 2013, the USFWS determined that the species did not warrant listing under the Endangered Species Act (USFWS 2013).

**General Habitat**

This species is found in mostly hilly or mountainous regions, in or near deciduous or evergreen forest, bottomland, floodplains, and sometimes in mostly open farmland (Arroyo-Cabrales and Álvarez-Castañeda 2008*a*, Bunch et al. 2015*b*). In Pennsylvania, this species was found in the foothills of mountains with an elevation of 2,000 feet (600 m) mostly in heavy hemlock forests (Mohr 1932). They have also been found at elevations of (675 m) in Georgia (Baker 1967, Baker and Patton 1967), (750 m) in Virginia (Johnson 1950), and (1,125 m) in Kentucky (Barbour 1951).

**Roosts and Roosting Behavior**

Overall, this species has been found in buildings, expansion joints of bridges, cliff crevices, caves, mines, towers, hollow trees, spaces beneath loose tree bark, and under the loose tarpaper of an old house.

In summer, eastern small-footed bats are known to use ground level rock roosts in talus slopes, rock fields and vertical cliff faces (Johnson et al. 2011), behind the door of a shed in Ontario (Hitchcock 1955), in limestone caves (Krutzsch 1966), under large flat rocks at the edge of quarries (Tuttle 1964), and beneath the bark of trees (Barbour and Davis 1969). The ceilings of caves are used as night roosts (Davis et al. 1965). Roost sites are often changed, sometimes daily, by both males and females of this species (J. S. Johnson et al. 2008). Non-reproductive females and males roost individually during summer, and during the breeding season males have been captured at entrances of caves, abandoned mines, and railroad tunnels (Amelon and Burhans 2006*b*). In South Carolina, eastern small-footed bat roosts have been found in a woodpile on a porch, a fish hatchery building, and a picnic shelter (Bunch et al. 2015*b*). There is also a spring record of a lone male found under loose tarpaper of an abandoned log cabin in Pickens County (Bunch and Dye 1999*a*). However, spring and summer roosts of eastern small-footed bats are largely unknown in South Carolina.

Roosts of maternity and nursery colonies of up to 33 bats have been reported in a cabin in North Carolina (O'Keefe and LaVoie 2011), behind loose bark in trees (Tuttle 1964), under exposed rocks on open ridges, and in the expansion joint of a concrete bridge (MacGregor et al. 1999). Reproductive females tend to choose maternity colony sites with high solar exposure, which is thought to decrease energy expenditure, provide thermal stability for young, and foster rapid offspring growth rates (Harvey and Redman 2001, Johnson and Gates 2008). Another factor in maternity site selection may be proximity to water (MacGregor and Kiser 1998). No maternity colonies have been located in South Carolina.

During winter, the eastern small-footed bat is one of the last to enter hibernacula and one of the first to leave, as they seldom enter before mid-November (Godin 1977, Gunier and Elder 1973,) and depart by early March (Mohr 1936). This species can be found hibernating in solution and fissure caves and mine tunnels, and usually prefers areas near the entrance where temperatures drop below freezing and the air is relatively dry (Barbour and Davis 1969, Gunier and Elder 1973). However, individuals will arouse from torpor and move to warmer locations, such as deeper inside caves, when temperatures fall below 15°F (-9°C) (Naughton 2012). Eastern small-footed bats are often found hibernating horizontally in narrow crevices and under rocks on the cave floor, or hanging from the wall or ceiling of the cave or mine (Davis 1955, Martin et al. 1966, McDaniel et al. 1982). They are also known to use shallow caves, and in Pennsylvania 52% of hibernacula identified were small caves of less than 500 feet (150 m) (Dunn and Hall 1989). In South Carolina, the winter roosting habits of this species are unknown, though an individual of undetermined sex in a rock outcrop crevice in mature hardwoods was recorded during winter in the mountains of Pickens County (Bunch and Dye 1999*a*). Eastern small-footed bats have high site fidelity to hibernacula and return to the same site each year (Gates et al. 1984). This species usually hibernates individually, but may also be found in small clusters. The largest hibernating colony discovered was that of 142 individuals in Ontario in February (Hitchcock 1949). Compared to other cave-hibernating species this bat is relatively active during hibernation, moving within and among hibernacula (Mohr 1942), and evidence indicates this species may not spend as much time in deep torpor (Mohr 1936, Hitchcock 1946, Tuttle 1964). These periodic arousals may be necessary to enhance immune function (Luis and Hudson 2006) and obtain enough water (Thomas and Geiser 1997).

**Reproduction**

Not much information about reproduction has been published for this species, though it is thought that it is similar to that of the little brown bat (*Myotis lucifugus*). Swarming to choose a mate occurs from late summer to early fall. Based on one reproductively active male found in September (Saugey et al. 1993), copulation probably occurs in the fall and the sperm is stored in the uterus of the female until spring. Gestation may last around two months, and a single pup is born in May or June (Peterson 1966, Barbour and Davis 1969, Godin 1977). It has been theorized that this species only gives birth to a single pup because the weight of more than one may be too great of a burden for the female to carry (Hitchcock et al. 1984), as the pup is 20 to 35% of the female's body weight (Kleiman and Davis 1979). According to anecdotal evidence form Hobson (1998), females may fly with newborns as early as June.

**Food Habits and Foraging**

Emerging at dusk shortly after sunset, the eastern small-footed bat flies slowly around a height of one to 10 feet (0.3 to 3 m) (Davis et al. 1965, Barbour and Davis 1969, van Zyll de Jong 1985), usually over water such as ponds and streams (MacGregor and Kiser 1998), but also in forest understory and canopy (Merritt 1987, Linzey 1998, Harvey et al. 1999*a*) and open fields (Neuhauser 1971). Because this species has short, broad wings and rounded wingtips, they are extremely maneuverable in dense vegetation (Norberg and Rayner 1987).

In South Carolina, they have been seen foraging over Reedy Cove Creek greater than 330 feet (100 m) downstream from the waterfalls (Bunch et al. 2015*b*). Activity of eastern small-footed bats has also been recorded at Eastatoe Creek and the northern reaches of Lake Jocassee, at nine of the 31 sites surveyed in April, July, and October (Webster 2013).

The diet of the eastern small-footed bat consists mainly of flying insects from Lepidoptera, Diptera, and Coleoptera (specifically moths, flies, and small beetles) but also consume Araneae and Orthoptera (spiders and crickets) (Moosman et al. 2007). When insects are abundant, this species may fill their stomach within an hour of the beginning of their foraging bout (Norberg and Rayner 1987). Eastern small-footed bats capture their prey while in flight or by gleaning prey off of a surface (Moosman et al. 2007).

**Seasonal Movements**
Eastern small-footed bats are commonly found in late summer flocks of migrating bats, but where they reside in other seasons is somewhat unknown (Barbour and Davis 1969). Migration may happen in late winter after eastern small-footed bats leave their hibernacula (Mohr 1933). However, this species may not undertake long migrations to hibernacula but hibernate near their summer range (van Zyll de Jong 1985). For example, two bats banded in an Ontario cave were reported to have not moved farther than about 12 miles (20 km) a few months later (Naughton 2012). Additionally, three females have been known to migrate 0.06 to 0.68 miles (0.1 to 1.1 km) to rocky outcrops within shale barren habitat from their winter hibernacula (Johnson and Gates 2008). The local availability of suitable habitat may play a large role in the distance this species migrates.

**Longevity and Survival**
An individual of this species is reported to have lived 12 years in the wild (Hitchcock 1965). The survival rate of eastern small-footed bats is thought to be relatively low. Based on banding data, the estimated mean annual survival for males is 0.76 years and for females is 0.42 years (Hitchcock et al. 1984).

**Threats**
Eastern small-footed bats are particularly vulnerable to external threats due to life history traits that make it slow to recover, such as a diffuse distribution, small population size, and low fecundity (USFWS 2011).

WNS threatens eastern small-footed bats as it has caused up to 100% mortality in some bat populations (Kunz and Tuttle 2009). WNS has been confirmed across large portions of the eastern small-footed bats' range, and sampled populations in New York, Massachusetts, and Vermont had already declined 78% overall between 2006 and 2009 (Langwig et al. 2009). According to Alves et al. (2014), an expected relative population reduction for this species is estimated to be 71.2% in an intermediate population-reduction scenario, compared to a pessimistic scenario at 96.6%, and an optimistic scenario at 29.3% population reduction. In the event of pessimistic and intermediate scenarios, this species will be considered Critically Endangered. Eastern small-footed bats are also at a greater risk of infection by WNS due to their tendency to roost near the entrance of hibernacula where exposure may be increased.

Disturbance and vandalism of hibernacula by human activities poses another large threat for this species (Tuttle 1979, Thomas et al. 1990, Caceres and Pybus 1997). Destruction of hibernacula is the main factor in population declines of bat species dependent on caves and mines (Humphrey 1978, Sheffield and Chapman 1992). Mine closures cause direct mortality to this species if they occur during hibernation. Even closing mines during non-hibernating periods forces eastern small-footed bats to burn critical fat reserves while searching for new hibernacula.

Pesticide poisoning, especially by organochlorines and anticholinestrase, is a threat to this species because it has been shown to cause population declines in insectivorous bats (Geluso et al. 1976, Reidinger 1976, Brady et al. 1982). Pesticides can also alter behavior, cause mortality, and be transferred to nursing young (Clark 1981, 1986, Henny et al. 1982). Eastern small-footed bats may be particularly vulnerable to environmental contaminants due to their association with mining activities and small size (Amelon and Burhans 2006*b*).

Eastern small-footed bats are vulnerable to habitat loss associated with natural resource exploitation due to their reliance on loose shale, talus, or karst formation often found in oil, gas, and mineral rich areas (Amelon and Burhans 2006*b*).

Because this species tends to roost in talus areas occurring on ridge tops, wind power development may adversely affect the eastern small-footed bat through habitat loss from construction (Amelon and Burhans 2006*b*). Bat mortality from turbines may also pose a threat, but this species is probably less vulnerable than other bats due to its low-flying habits. No wind turbines have been placed in South Carolina to date, however, Clemson University is constructing a test facility for turbines at the coast (Bunch et al. 2015*b*).

Another threat to this species is the inadequacy of existing regulations for management of forestry, wind energy development, and oil, gas, and mineral extraction, especially when it comes to the protections afforded a state-listed species. These protections are meant to prevent trade or possession of state-listed species, but do not to protect against habitat destruction (USFWS 2011). Many of forms of habitat alterations may also increase predation by natural predators.

Global climate change may be a potential threat to eastern small-footed bats, since (like all bats) they depend highly on temperature for important processes such as hibernation, reproduction, and growth. A change in climate may also make southern hibernation sites unsuitable due to increased temperatures (Bunch et al. 2015*b*). This threat has the potential to cause eastern small-footed bats to deplete energy reserves through more frequent arousal from torpor since this species hibernates in areas more susceptible to fluctuations in temperature than those that hibernate in the cave interior (Humphries et al. 2002, Rodenhouse et al. 2009). Continued change in temperature and precipitation may also affect this species indirectly by changing the availability of their insectivorous prey (Bale et al. 2002).

**Conservation Measures**

Bat exclusion, not extermination, is the most effective and humane way to remove bats from buildings. Sealing out bats and/or adding more light to the roost of a colony are more effective alternatives than use of pesticides for control purposes (Laidlaw and Fenton 1971, Barclay et al. 1980). To minimize negative impacts to eastern small-footed bats, eviction from buildings should include appropriately timed exclusion methods. To avoid the maternity period, bats should not be evicted from May through July. Alternatively, populations at the roost area may be decreased by 41 to 96% if lights are introduced to the area (Laidlaw and Fenton

1971). Measures should be taken to provide species-specific alternate roost structures in the event of a disturbance, such as multi-chamber nursery boxes for eastern small-footed bat colonies.

Recommendations from NatureServe (2015) state that caves and mines which serve as hibernacula should be protected during the hibernation period from November through March, and include a buffer zone to protect from disturbances such as logging that might change water and airflow, temperature, and humidity. Additionally, maternity colony roosts and surrounding habitat should be protected during late spring and early summer, with adjacent foraging areas protected from deforestation. Other habitat protection and management recommendations from Bunch et al. (2015*b*) include working to prevent or reduce disturbance to natural and artificial roost structures, as well as to maternity colonies and hibernacula through gating, warning or interpretive signs, prevention of trails or roads to these sites, and other protective measures; designate no-cut buffer zones around known roosts; provide forested corridors between harvested units; and protect foraging areas and migration corridors, which could be done through landowner incentive programs, conservation easements, lease agreements, or purchases. Other measures may include providing, protecting, and maintaining large diameter roost trees, large snags, decadent trees, hollow trees, and roost structures, especially near water or riparian areas; attempting to create or maintain patches of structurally diverse forest in order to provide a wide variety of suitable roosting and maternity sites; minimizing large-scale pesticide use whenever possible; and protecting habitat above or around maternity roosts and known foraging areas from pesticides.

Priority survey and research recommendations from Bunch et al. (2015*b*) include working to determine feeding patterns and summer and winter roost site requirements for eastern small-footed bats; determine if prescribed fire represents any threat, and what the acceptable distances are of fire, smoke and fire lines from roosts; identify colonies and monitor colony size, persistence, and roost sites long term; conduct seasonal surveys at caves and mines being considered for closure; evaluate roost and appropriate food (insects high in polyunsaturated fats) availability, as well as roost temperatures, and compare these factors with winter survival. Further research is greatly needed to identify the best placement of wind turbines, as well as strategies that would minimize impacts to bats (Ellison 2012). The SCDNR Heritage Trust tracks high priority species including the eastern small-footed bat, and researchers are requested to submit bat data and occurrence records to their database.

Education and outreach goals recommended by Bunch et al. (2015*b*) include working to create general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans.

# Evening Bat (*Nycticeius humeralis*)

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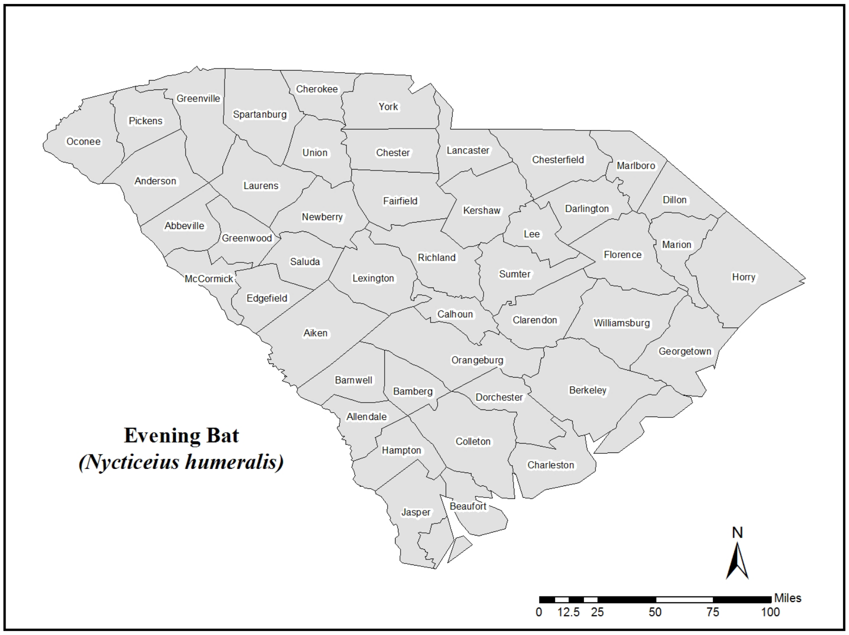
**Description**
The evening bat is a medium sized bat with dark brown pelage above and paler below, generally with light ash-gray hair tips on the dorsal area. According to Kurta (2001), a common agricultural pest eaten by this species is the corn rootworm, and 1.25 million insects can be consumed in a single season by 100 evening bats. Also, females produce a litter that is the largest in relation to maternal size of all bats, which is 50% of her postpartum body mass. This species resembles many other bats from the *Myotis* genus and the big brown bat, but misidentification is avoided by the identification of the two upper incisors versus the four in *Myotis* species and the big brown bat, as well as the characteristically rounded, curved tragus found in evening bats. Additionally, evening bats can be separated from the big brown bat by their smaller size and absence of a keel on the calcar (Barbour and Davis 1974).

**Identification**
Evening bats weigh 0.2 to 0.5 ounces (7 to 14 gr) and have a wingspan of 10 to 11 inches (26-28 cm) (Harvey et al. 2011). This species has a short, broad skull and the ears are short and rounded. The pelage is dark brown to blackish-brown on the upper side, and slightly lighter in color on the lower. The uropatagium on evening bats is furred at the base, but the dark brown-black ears, nose, and the rest of the wing membranes are hairless. Sexual dimorphism exists in the evening bat, with females consistently heavier than males.

**Taxonomy**
Currently there are three recognized subspecies of the evening bat (Wilson and Reeder 2005), and only *Nycticeius humeralis humeralis* has been confirmed in South Carolina (Hall 1981).

**Distribution**
The evening bat is found throughout most of the eastern US and northeastern Mexico. It ranges north from Nebraska, Iowa, southern Michigan, Pennsylvania, and New Jersey to west in Kansas and eastern Texas, and south to Veracruz, Mexico. In the southern Appalachians this species is rare or absent (Barbour and Davis 1974, Webster et al. 1985). In South Carolina, it is common throughout the majority of the state and occurs in all physiographic provinces (M. A. Menzel et al. 2003).

**Population Status**
Less common throughout most of its range, in the southern coastal states the evening bat is one of the most common bat species (Harvey et al. 2011). This species is ranked as Globally Secure (G5), Nationally Secure (N5), and Subnationally unranked (SNR) (NatureServe 2017). However, it is currently ranked as Subnationally secture (S5) by the




SCDNR Heritage Trust (see Table 2). The evening bat is currently classified as Least Concern (LC) on the IUCN Red List (Arroyo-Cabrales and Álvarez-Castañeda 2008*b*). It is considered locally common and is not listed as a Priority species in the South Carolina 2015 SWAP (SCDNR 2015).

**General Habitat**
Historically, evening bats were probably associated with bottomland forests, swamps, and wetlands (Amelon and Burhans 2006*c*). Today they are a forest dwelling species that inhabit eastern deciduous forests at elevations from sea level to 980 feet (300 m) (Watkins 1972), and are commonly found along waterways (Schmidly 1991).

**Roosts and Roosting Behavior**
The evening bat prefers to roost in hollow trees, the underside of loose bark, or in buildings (Barbour and Davis 1969, Chapman and Chapman 1990, Menzel et al. 2001*a*). In Florida, evening bats have also been found in Spanish moss (*Tillandsia usneoides*) (Jennings 1958) and underneath palm fronds (Taylor and Lehman 1997). This species rarely roosts in caves as only one record of cave roosting has been reported in Missouri (Easterla 1965).

During summer, evening bats selected roost sites differently based on landscape conditions in Georgia. Day roosts selected on the natural site were based on tree, plot, and landscape characteristics, but on the managed site bats selected day roosts at the tree and plot scale (Miles et al. 2006). In southwestern Missouri, evening bats selected trees in late stages of decay (Boyles and Robbins 2006). At the Savannah River Site in South Carolina, roosts were in cavities or under exfoliating bark most commonly found in longleaf pines (*Pinus palustris*), though conifer snags in beaver ponds were also common. Menzel et al. (2000) also reported that, compared to random plots, roosts were found in areas where the canopy was taller and less dense, there was greater snag abundance, the overstory had less trees and lower richness, and the understory had less trees, lower richness and lower diversity. In the lower coastal plain of South Carolina, evening bats roosted in cavities in hardwood trees and fork-topped loblolly pines (*Pinus taeda*), with both male and female evening bats selecting roost sites in mixed-pine hardwoods (Hein 2008). Also in this study, about 40% of male and 20% of female roosts were located in forested corridor stands.

Nursery roosts may be located in hollow cypress trees, behind the loose bark of dead pines, in Spanish moss, and in buildings and attics (Jennings 1958, Cope et al. 1961, Watkins and Shump 1981, Menzel et al. 2001*a*). Nursery colonies may vary from 25 to 950 individuals (Watkins 1969). Adult males are not present in these colonies, and male offspring disperse from the nursing colony before females (Watkins and Shump 1981, Bain and Humphrey 1986). Roosts in attics vary from 46° to 113°F (8° to 45° C) when nursery colonies are present, and individuals are known to spread out at higher temperatures (Watkins 1972). In South Carolina, Menzel et al. (2001) found that evening bat maternity colonies used mature longleaf pine stands with a higher overstory, greater canopy density, and greater proportion of basal area composed of conifers compared to roosts used by solitary evening bats surrounding the maternity colony. Of the 33 maternity colonies found in South Carolina by Hein (2008), 15 smaller colonies of 4 to 27 bats were in fork-topped trees and 18 larger colonies of over 22 bats were found in tree cavities. Also, four of the cavity trees had greater than 50 individuals, and two of these had over 100.

Not much is known about the winter habitat of the evening bat in southern states. In southwestern Missouri, Boyles and Robbins (2006) reported differences in tree versus habitat-level roosts between seasons, and that habitat characteristics were more important than tree characteristics in explaining this variation. During winter in this study, this species selected a higher proportion of live trees than in summer, and trees were located in areas with lower average tree height and higher densities of trees. The northern breeding populations of evening bats may migrate south for the winter, as males and females are found in southern states during this time from South Carolina to Arkansas (Watkins 1972), and it is thought that they are active during warm periods. However, winter roosting habits in southeastern states, including South Carolina, have not been described (Whitaker and Hamilton 1998). In Florida, evening bats have been known to use buildings as winter roosts (Bain 1981). In South Carolina, there have been winter records of this species in attics in Charleston County (M. A. Menzel et al. 2003).

**Reproduction**

The sexes segregate during the reproductive period for this species (Watkins 1972). Mating occurs in the fall, and in Florida it beings in October and occurs throughout winter (Bain and Humphrey 1986). Sperm is stored in the female's uterus until spring when fertilization takes place. Adult females arrive at nursery roosts around the second week of April in South Carolina (Golley 1966). In the south, the birth of one to three pups (average of two) occurs from the middle of May to the middle of June (Watkins 1972). A higher rate of growth of the young tend to occur in smaller, crowded roosts (Watkins 1972). Some evening bat females are known to nurse offspring that are not their own, and it has been hypothesized that this may be a way of getting rid of excess milk (Wilkinson 1992). Young begin to fly by three weeks, reach the size of an adult within a month, and are weaned between six to nine weeks (Jones 1967, Schmidly 1991). By late August, most individuals have left their nursery colonies (Baker 1965). It has been reported that juvenile males are reproductively mature at less than one month old (Bain and Humphrey 1986). However, in a study conducted by Millis (2013), the average age at sexual maturity for males born before mid-July was about four months old. It is unknown when females reach sexual maturity, though like other temperate bat species, they may build fat reserves during the first year instead of entering the reproductive population (Burnett and Kunz 1982).

**Food Habits and Foraging**

Evening bats emerge from their roosts relatively early, leaving around dusk (Lowery 1974). For this species, foraging activity peaks in the early evening, and again just before dawn (Watkins 1971). They have a steady, slow flight, and begin at a height of about 43 to 82 feet (13 to 25 m), flying much closer to the ground as night falls (Harper 1927, Lowery 1974). Though they are considered a clutter-adapted species, a substantial amount of foraging activity still happens above, compared to below or within, forest canopy, in South Carolina (Menzel et al. 2005*b*).

Wetlands, bottomlands, and riparian areas are the primary foraging habitat of this species (Menzel et al. 2002, Schmidly 1991). In Georgia, 76% of foraging habitat was over slash-loblolly pine (Krishon et al. 1997). At the Savannah River Site in the Upper Coastal Plain of South Carolina, evening bats were found using pine savannahs (Ford et al. 2006*a*), as well as in gaps in bottomland hardwood and swamp forests, and over beaver ponds (Menzel et al. 2001*a*). Menzel et al. (2005) found riparian areas were more actively used than upland habitat. In a study by Carter (1998), habitat types within home ranges of six evening bats were used in the same proportion that they were available, and included pine forests and bottomland hardwoods. Carter et al. (2004) found that evening bats were most active in pine forests (59%) and bottomlands (37%) and rarely foraged in upland hardwoods. Menzel et al. (2003) found most evening bat activity over Carolina bays, as well as grassy areas and bottomland hardwoods. Additionally, activity was highest in clearcuts and young stands, moderate in stands greater than 60 years old, and lowest in stands between 21 to 60 years old. The activity of evening bats has also been recorded at nine out of 31 sites around Lake Jocassee and Lake Keowee in the spring and summer, but not in the fall, suggesting migration northwestward into the Upper Piedmont in spring and southeastward migration out of the Upstate in fall (Webster 2013).

Evening bats feed on Coleoptera, Diptera, Hymenoptera, Hemiptera, Homoptera, and Lepidoptera, which specifically include June beetles, Japanese beetles, flying ants, spittle bugs, and moths (Ross 1967, Mumford and Whitaker 1982, Feldhamer et al. 1995, Carter 1998, Bat Conservation International 2015). In South Carolina, Carter found that in midsummer this species feeds primarily on Coleoptera and Hymenoptera, and in later summer consumes Hemiptera and Homoptera as well (Carter 1998, Carter et al. 2004). One evening bat in South Carolina was found to exclusively feed on Lepidoptera (Donahue 1998). This is a species that uses its tail and wing membranes to capture prey during feeding maneuvers (Linzey and Brecht 2005).

**Seasonal Movements**

Little is known about migratory movements of the evening bat. It is thought that northern breeding populations migrate south beginning in mid-October (Watkins 1972) because they are absent there after that time, and because there are reported recoveries of this species from banding studies (Humphrey and Cope 1968). However, in the southern portions of its range, this species may be a winter resident from Texas to as far north as Arkansas (Baker and Ward 1967, Schmidly 1991). In South Carolina, it seems this species is resident because both sexes have been reported year round (Golley 1966). Several evening bats have been found to travel 340 miles (547 km) south of their original summer banding site locations (Humphrey and Cope 1970), and have homing distances ranging from 38 to 95 miles (61 to 153 km) (Cope and Humphrey 1967, Watkins 1969).

**Longevity and Survival**

Evening bats are thought to have an average life span of two years in the wild, though some individuals have lived for over five years (Watkins 1972).

**Threats**

The population trends of this species are relatively unknown, though the evening bat is considered state endangered in Indiana where it has best been monitored. This species does appear to be abundant in Missouri and Iowa (Arroyo-Cabrales and Álvarez-Castañeda 2008*b*).

Disturbance or destruction of natural and artificial roost structures are a threat to this species. Evening bats often use buildings and are considered highly sensitive and less tolerant to disturbances by humans compared to big brown bats (*E. fuscus*) (Whitaker and Gummer 1993). There are numerous reports of roosting and nursery colony abandonment due to excessive disturbance, banding and radio telemetry studies, and survey and netting operations (Watkins 1969, Bain 1981, Clem 1992).

Pesticide poisoning, especially by organochlorines and anticholinestrase, is a threat because it has been shown to cause population declines in insectivorous bats (Geluso et al. 1976, Reidinger 1976, Brady et al. 1982). Pesticides may alter behavior, cause mortality, and be transferred to nursing young (Clark 1981, 1986, Henny et al. 1982). Because evening bats consume crop pests, they may also have an increased risk of contamination from the accumulation of organochlorine pesticides in their body fat. When the fat is metabolized either during migration or hibernation, exposure to these pesticides is increased and can be lethal (Bennett and Monte 2007).

Habitat loss in the form of exclusion and eradication in buildings, removal of old buildings, and conversion of bottomland hardwoods and wetlands threatens evening bats (Amelon and Burhans 2006*c*). Additionally, foraging habitat may be reduced by increased urbanization and loss of riparian habitat. Many of these forms of habitat alterations can also cause increased predation by natural predators. Other potential threats to this species include chemical pollution (Tuttle 1979), waterway siltation (Tuttle 1979), and flooding (Hall 1962).

**Conservation Measures**

Bat exclusion, not extermination, is the most effective and humane way to remove bats from buildings. Sealing out bats and/or adding more light to the roost of a colony are more effective alternatives than use of pesticides for control purposes (Laidlaw and Fenton 1971, Barclay et al. 1980). To minimize negative impacts to evening bats, eviction from buildings should include appropriately timed exclusion methods. To avoid the maternity period, bats should not be evicted from May through July. Alternatively, populations at the roost area may be decreased by 41 to 96% if lights are introduced to the area (Laidlaw and Fenton 1971). Measures should be taken to provide species-specific alternate roost structures before eviction, and typical bat boxes, multi-chamber nursery boxes, and structures that mimic large hollow trees may all be reasonable alternatives for evening bats.

Other habitat protection and management recommendations for other South Carolina bat species from Bunch et al. (2015*b*) include working to prevent or reduce disturbance to natural and artificial roost structures, as well as to maternity colonies and hibernacula through gating, warning or interpretive signs, prevention of trails or roads to these sites, and other protective measures; retain and recruit cypress-gum swamp forests with large cavity trees; designate no-cut buffer zones around known roosts; provide forested corridors between harvested units; and protect foraging areas and migration corridors, which could be done through landowner incentive programs, conservation easements, lease agreements, or purchases. Other measures may include protecting or managing for longleaf pine stands with a higher overstory, greater canopy density, and greater proportion of basal area composed of conifers, since these habitats are particularly important for nursing colonies in South Carolina (Menzel et al. 2001*a*). Additional measures may include providing, protecting, and maintaining large diameter roost trees, large snags, decadent trees, hollow trees, and roost structures, especially near water or riparian areas; attempting to create or maintain patches of structurally diverse forest in order to provide a wide variety of suitable roosting and maternity sites; minimizing large-scale pesticide use whenever possible; and protecting habitat above or around maternity roosts and known foraging areas from pesticides.

Priority survey and research recommendations from Bunch et al. (2015*b*) include conducting seasonal surveys at caves and mines being considered for closure; evaluating roost and appropriate food (insects high in polyunsaturated fats) availability, as well as roost temperatures, and compare these factors with winter survival. Other similar measures may include conducting seasonal surveys to identify and monitor roosting and maternity sites, and at buildings being considered for demolition. Further research is greatly needed to identify the best placement of wind turbines, as well as strategies that would minimize impacts to bats (Ellison 2012). Researchers are requested to collect and record bat data, but the SCDNR Heritage Trust does not track this species in its database.

Education and outreach goals recommended by Bunch et al. (2015*b*) include working to create general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans.

# Hoary Bat (*Lasiurus cinereus*)

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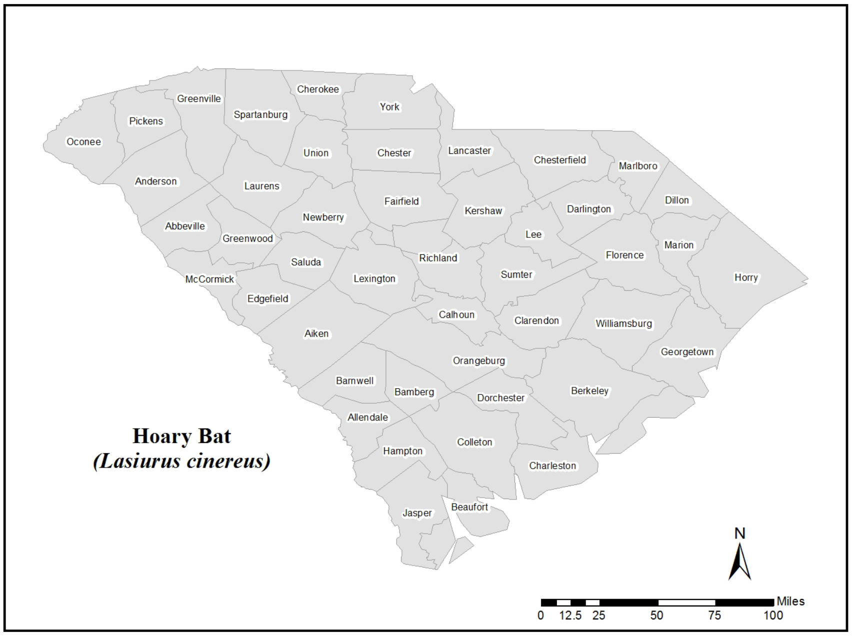
**Description**
The hoary bat is the largest bat species in South Carolina, and has the widest range and is considered one of the faster bat species in North America (Barbour and Davis 1969). The pelage is striking compared to most bats, with a rich coloring of yellow, grey-brown, and dark brown with white tips that give this species a distinctive frosted or "hoary" appearance. The high wing loading and high aspect ratio of this species indicates that it is a fast, straight flier (Farney and Fleharty 1969). The migratory speed of this species can exceed 13 miles per hour (21.3 km/h) (Shump and Shump 1982*a*). Unfortunately, the hoary bat is the most prevalent among fatalities reported at wind-energy facilities in North America (Ellison 2012), and compose about half of an estimated 450,000 bat fatalities at wind facilities annually in North America (Cryan 2011).

**Identification**
The hoary bat weighs 0.9 to 1.1 ounces (25 to 30 grams) and has a wingspan of 8 to 10 inches (21 to 25 cm) (Harvey et al. 2011). This species has thick, dense, soft fur on the uropatagium and body that is highly insulative. The pelage is yellowish-brown to mahogany on the upper side, with white patches on the shoulders and wrists, and a patch of yellow on the throat. The hoary bat has a heavily furred membrane to the tip of its tail. The ears are rounded, thick, and edged black with the outer portion densely furred. The tragus is broad and short. Females tend to be about 4% larger than males (Williams and Findley 1979).

**Taxonomy**
Currently there are three recognized subspecies of the hoary bat (Wilson and Reeder 2005). *Lasiurus cinereus cinereus* is the only subspecies found in South Carolina (Shump and Shump 1982*a*). Note that a molecular study in 2015
reassessed the evolutionary relationships of tree bats of the genus Lasiurus, recommending the recognition of 3 separate genera: Lasiurus (red bats), Dasypterus (yellow bats), and Aeorestes (hoary bats) (Baird et al. 2015). Thus the taxonomy of this species may also be recognized as *Aeorestes cinereus.*

**Distribution**
The hoary bat has the broadest geographic distribution of bat species in the New World, and occurs from southern Canada through most of South America, including most of the US (except southern Florida) and Hawaii. This species winters in southern California, the southeastern US, Mexico, and Guatemala (Shump and Shump 1982*a*). In South Carolina, this species has a more extensive distribution than any other bat, and is found statewide in all four physiographic provinces (M. A. Menzel et al. 2003). However, hoary bats are probably rare in the state during summer due to their migratory patterns.




**Population Status**
This hoary bat is less common in the eastern US and northern Rockies than it is in the prairie states and northwestern US (Shump and Shump 1982*a*). This species has a rounded rank of Globally Vulnerable (G3G4), Nationally Secure (N5), and Subnationally unranked (SNR) (NatureServe 2017). It is currently classified as Least Concern (LC) on the IUCN Red List (Gonzalez et al. 2008). However, no population trend data exists for the hoary bat (NatureServe 2017), and it is listed as a Highest Priority species in the South Carolina 2015 SWAP (SCDNR 2015).

**General Habitat**
Due to the extensive range of the hoary bat, this species is found in an extremely wide variety of habitats. In the western US these habitats include the arid deserts and ponderosa pine forests, and in the East, pine-hardwood forests (Tuttle 1995). Additionally, they are seldom found in urban settings, and are most abundant in coniferous forests in the Pacific Northwest and deciduous forests of the plains states in the US (Tuttle 1995). The wide elevation range hoary bats are found in varies from sea level in the Pacific Northwest (Nagorsen and Brigham 1993) to 10,170 feet (3,100 m) in Colorado (Jung et al. 1999).

**Roosts and Roosting Behavior**
Hoary bats have been found to roost solitarily in tree foliage and tree cavities at the edge of clearings (Constantine 1966). Day roosts used by this species are almost exclusively in the foliage of trees (Shump and Shump 1982*a*, Willis and Brigham 2005). Shump and Shump (1982) reported roosts in trees such as elm (*Ulmus* species), black cherry (*Prunus serotina*), plum (*Prunus* species), box elder (*Acer negundo*), and osage orange trees (*Maclura pomifera*) at about 10 to 16 feet (3 to 5 m) above the ground. They have also been found under a driftwood plank (Connor 1971), and in a gray squirrel nest (Neill 1952).

During summer, hoary bats generally segregate by sex, with males tending to occur in mountainous regions in western North America and the females in eastern regions (Shump and Shump 1982*a*). In Iowa, roosts with an open space below and dense shade and cover above and to the sides were selected (Constantine 1966). In the same study, roosts were mainly found in trees on the edges of forests or fencerows next to crops distant from human populations, and roosted on the side of the tree facing the lower, crop area. However, in Wyoming a roost had higher odds of being chosen with increasing tree height and percent canopy cover at the tree, and decreasing distance to the nearest water and habitat edge (Gruver 2002). In central Ontario, Jung et al. (1999) reported that late successional forests were often occupied by hoary bats, and hypothesized that they used these areas because improved foraging opportunities may be available in old-growth forest with open canopies.

Reproductive females generally roost solitarily with young in tree foliage, and may choose a roost site based on microclimate factors. In Saskatchewan, Canada, roost sites chosen by reproductive females in mature white spruce (*Picea glauca*) were found at the same height as the surrounding forest and on the southeast side of trees, where protection from westerly winds and increased sun exposure resulted in significant energy savings (Willis and Brigham 2005). A female and her young may change roosts often (Veilleux et al. 2009), or use the same roost site for over two weeks (Nagorsen and Brigham 1993, Willis and Brigham 2005).

In fall and winter in California, there appears to be altitudinal separation between the sexes, with males occurring at higher elevations than females (Vaughan and Krutzsch 1954). During winter hoary bats are known to roost in tree foliage, Spanish moss, tree cavities, and squirrel nests (Neill 1952, Cowan and Guiguet 1965, Constantine 1966), but not typically in caves (Myers 1960). In South Carolina, very little is known about night roosts, migration roosts, summer roosts, or winter roosts of hoary bats.

**Reproduction**

Mating probably occurs in flight during fall migration or on the wintering ground, and sperm is stored in the female's uterus until spring when fertilization takes place (Shump and Shump 1982*a*). Between one to 4, or an average of 2, pups are usually born from mid-May to early July (Bogan 1972, Shump and Shump 1982). Gestation lasts 90 days, young begin to fly by 33 days, and are weaned at seven weeks (Shump and Shump 1982*a*, Whitaker and Hamilton 1998, Koehler and Barclay 2000). Females carry young during flight until they are six to seven days old (Bogan 1972). Postnatal growth is relatively slow, which may be a trait of migrant bats to be able to forage all year (Koehler and Barclay 2000). Sexual maturity of males and females is usually obtained by their first fall (Cryan et al. 2012). Generally young are born and reared in the northeastern, midwestern, and prairie states in the US, and a few as far south as Arkansas, Louisiana, and Tennessee (NatureServe 2017).

**Food Habits and Foraging**

Foraging by hoary bats does not begin until later in the evening, after many other bat species have already left their roosts (Barbour and Davis 1969). Hoary bats forage all night, and activity tends to peak during the middle of the night (Shump and Shump 1982*a*, Barclay 1985). This species was most active one hour and 40 minutes past sundown in New Mexico (Jones 1965), but most active four to five hours after sunset in Iowa (Kunz 1971). However, the time of emergence and length of foraging bouts for adult females depends on their reproductive stage and number of pups, and ultimately foraging time gradually increases until young fledge (Barclay 1989). Hoary bats may also forage on warm winter days, emerging in the late afternoon (Barclay 1989, Whitaker and Hamilton 1998). There is little data available for distances hoary bats travel from roost sites to foraging sites, and may depend on local factors such as prey availability and abundance. Foraging areas may be located over a mile (1.6 km) away from diurnal roosts (NatureServe 2017), and could include woodland, riparian, and wetland habitats in open areas within the forest, above the forest canopy, and over lakes and streams (Shump and Shump 1982*a*, Barclay 1985, Nagorsen and Brigham 1993). In New Mexico, migrating females foraged along streams below the canopy (Valdez and Cryan 2009). In Manitoba, this species foraged in the lee of a forested ridge surrounded by wet meadows, marshes, and bays where there was less wind (Barclay 1985). Sometimes foraging territories are established (Barclay 1984), and they may forage at a wide range of air temperatures, from 32°F to 72°F (0°C to 22°C) (Jones 1965). In South Carolina, the activity of hoary bats has been recorded widely around Lake Jocassee and Lake Keowee, in April, July and October at 29 of the 31 sites surveyed (Webster 2013).

Hoary bats are foraging specialists as they feed on relatively few orders of insects compared to other bats, and seems to prefer Lepidoptera (Ross 1967, Black 1972). In New Mexico during spring migration, this species mainly fed on moths along streams until late spring when the focus on moths appeared to decline, potentially due to differential prey selection and/or seasonal prey abundance (Valdez and Cryan 2009). However, this species is also known to consume Coleoptera, Diptera, Orthoptera, Isoptera, Odonata and Hymenoptera, which more specifically includes grasshoppers, dragonflies, and wasps (Ross 1967, Whitaker 1972, Black 1974, Whitaker et al. 1977, Rolseth et al. 1994).

In South Carolina, the foraging habits of hoary bats are not well understood. Three hoary bats studied by Menzel et al. (2003), were recorded on 5.2% of all survey locations at the Savannah River Site. Of those recorded locations, 18.8% were in lake and pond habitat, 7.6% in bottomland hardwoods, 6.8% in grass-brush habitat, 5.0% in loblolly-slash habitat, and 1.4% in longleaf habitat. No records were found in upland hardwood or pine-hardwood habitats. Though activity was low throughout the study site, the highest concentration of activity was in bottomland hardwoods greater than 60 years old.

**Seasonal Movements**

The hoary bat is highly migratory, and is thought to migrate to southern California, the southeastern US, Mexico and Guatemala for winter (Shump and Shump 1982*a*). However, some hoary bats may remain in northern states and hibernate as they have been found in December and January in Michigan, New York, Connecticut, and Indiana, as well as other northeastern and northwestern states (Whitaker et al. 1980, Shump and Shump 1982*a*, Cryan 2003). Migration during spring probably occurs from April to June (Koehler and Barclay 2000, Cryan 2003, Valdez and Cryan 2009). Female hoary bats generally leave about one month earlier than males, and tend to migrate further than males from wintering grounds in California and Mexico when returning north in the early spring (Cryan 2003, Valdez and Cryan 2009). Migration during fall probably occurs between August and October (Nagorsen and Brigham 1993, Koehler and Barclay 2000, Cryan 2003). The migration patterns of the hoary bat differ depending on the season; fall migration is composed of larger, more organized groups than spring migration (Cryan 2003, Shump and Shump 1982). However, migration routes in both seasons are not well understood. In South Carolina, most individuals of this species probably migrate north in spring and back again in fall or winter. However, there is evidence that some hoary bats are found in the state in the summer (M. A. Menzel et al. 2003).

**Longevity and Survival**

The hoary bat is thought to live up to six or seven years (Tuttle 1995).

**Threats**

Wind turbine facilities are the biggest major threat to this species. Hoary bats fatalities are the most prevalent fatalities documented at wind-energy facilities in late summer and early fall (Ellison 2012), and compose about half of an estimated 450,000 bat fatalities at wind facilities annually in North America (Cryan 2011). Because the hoary bat is one of three migratory tree bats that compose the majority of wind turbine fatalities, it has been suggested that seasonality and migration patterns make them more vulnerable to collisions (Cryan 2011). For example, ridge tops may be a major topographical feature used by bats during migration, and facilities built on ridge tops appear to have the highest bat fatalities (Johnson and Erickson 2008). No wind turbines have been placed in South Carolina to date, however, Clemson University is constructing a test facility for turbines at the coast (Bunch et al. 2015*b*). Additionally, deadly collisions with towers in Florida have been recorded for this species (Crawford and Baker 1981).

Timber harvest of larger trees, and jays in suburban areas may be potential threats to hoary bats (Bolster 2005). Habitat and roost site loss due to development and removal of palm fronds are other potential threats for this species (Bunch et al. 2015*c*). The harvesting of Spanish moss may still be a threat in some areas, but the development of synthetic materials replacing the need for Spanish moss may have reduced this threat (Trani et al. 2007). Also, natural causes such as hurricanes may also create loss of habitat as well as direct mortality (Bunch et al. 2015*c*).

Pesticides on forested public lands may cause mortality to both this species and the insects they prey upon (Bolster 2005). Pesticide poisoning, especially by organochlorines and anticholinestrase, is a threat to this species because it has been shown to cause population declines in insectivorous bats (Geluso et al. 1976, Reidinger 1976, Brady et al. 1982). Pesticides can also alter behavior, cause mortality, and be transferred to nursing young (Clark 1981, 1986, Henny et al. 1982).

**Conservation Measures**

Wind turbines are a relatively new threat, and thus very little research has been conducted on how to minimize the dangers of turbines to bats. What is known is that the new larger, taller turbines have decreased mortality in birds but actually increased bat fatalities (Barclay et al. 2007), and that facilities built on ridge tops appear to have the highest bat fatalities (Johnson and Erickson 2008). Research is greatly needed to identify the best placement of turbines, as well as strategies that would minimize impacts to bats (Ellison 2012). Wind turbine management recommendations from Bunch et al. (2015*c*) include working with wind energy development companies to mitigate the impacts of wind turbines, such as increasing the cut-in speed of turbines to reduce mortalities; and establishing timing and location of potential wind-energy conflicts through pre-construction surveys and determine potential mitigation measures to reduce mortality to hoary bats. Also, using flashing lights instead of constant lights on towers, which is now regarded as acceptable by the FAA, can reduce bat mortality (Bunch et al. 2015*a*).

Other habitat protection and management recommendations from Bunch et al. (2015*c*) include working to minimize bat mortality during prescribed burn activities by burning in the spring or summer; advise forestry professionals to conduct controlled burns when minimum night temperatures are > 39°F (4°C) and temperatures at the time of ignition are > 50°F (10°C); maintain hedgerow habitats along crop borders; retain large trees in urban areas, and Spanish moss and old palm fronds on public lands; and timber management in the Piedmont region that includes pine thinning or controlled burns may benefit this species by creating more open forest areas. Other measures may include working to minimize or carefully consider large-scale pesticide use whenever possible, and protect habitat above or around maternity roosts and known foraging areas from pesticides.

Priority survey and research recommendations from Bunch et al. (2015*c*) include conducting further research to better understand general habitat requirements, population status, summer and winter roost sites, winter habitat, migration information, and behavior of hoary bats; determine the extent and seasonality of off-shore commuting and foraging to assess vulnerability of hoary bats to off-shore wind development; and determine the vulnerability of hoary bats, especially during fall migration, to coastal wind energy development. The SCDNR Heritage Trust tracks high priority species including the hoary bat, and researchers are requested to submit bat data and occurrence records to their database.

Education and outreach goals recommended by Bunch et al. (2015*c*) include creating general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans; and discourage the practice of removing roosting habitat such as old palm fronds and large amounts of Spanish moss from trees.

# Little Brown Bat (*Myotis lucifugus*)

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## Description

Though it is one of the most common bats throughout most of the northern US and Canada, in the southern part of its range the little brown bat is scarce or only common locally (Harvey et al. 2011). Aided by its high maneuverability and a fast rate of mastication, this species is well adapted to rapidly consuming swarms of small insects (Kallen and Gans 1972, Fenton and Bell 1979), and can eat 150 mosquitoes in 15 minutes (Fenton 1983, Tuttle 1988). The longest life span of this species has been recorded at an impressive 30 years (Keen and Hitchcock 1980). WNS has greatly impacted populations of little brown bats in its northern range and threatens to push some populations to near extinction (Frick et al. 2010*a*).

## Identification

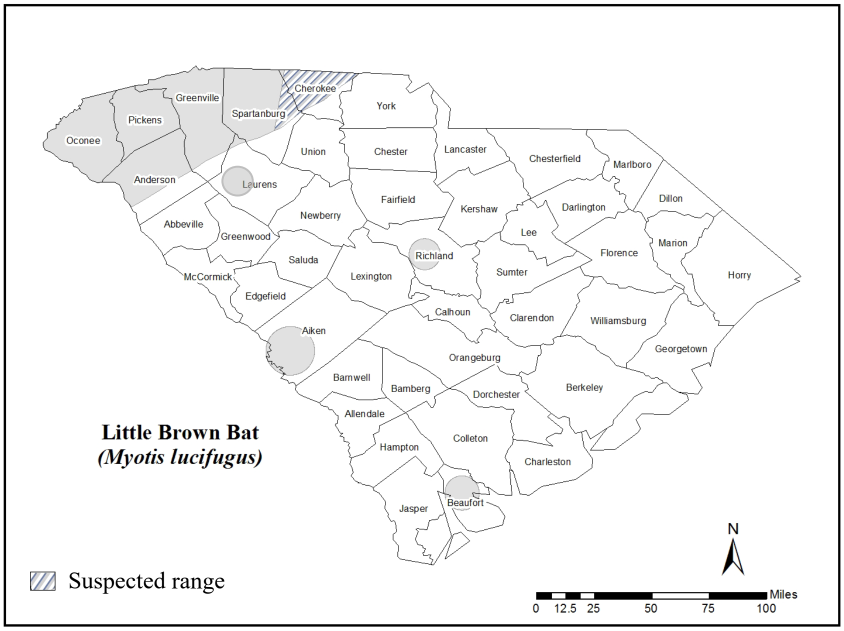
The little brown bat is small to medium sized weighing 0.2 to 0.5 ounces (7 to 14 gr), and has a wingspan of 9 to 11 inches (22 to 27 cm) (Harvey et al. 2011). Its pelage is dark brown to cinnamon-buff with long glossy tips on the dorsum, and pale gray to buffy below. The ears and membranes of the wing and tail are dark brown to black. The ears are narrow and pointed, and the medium sized tragus is blunt. When the ears are gently pressed forward, they reach only to the nostrils. The calcar is not keeled, and the hind foot is relatively large. Females tend to be slightly larger than males in weight (especially during winter) and head, body, and forearm lengths (Fenton 1970, Williams and Findley 1979). This small brown bat resembles the northern long-eared bat (*Myotis septentrionalis*), but misidentification is avoided by the identification of the long, pointed tragus and ears that extend well beyond the nose in the northern long-eared bat (Fenton and Barclay 1980). Additionally, the hairs on the feet of extend beyond the nail in the little brown bat but not in the northern long-eared bat.

## Taxonomy

Currently there are five recognized subspecies of the little brown bat (Wilson and Reeder 2005). *Myotis lucifugus lucifugus* is the only subspecies found in South Carolina (Fenton and Barclay 1980).

## Distribution

Little brown bats range from central Alaska and southern Canada into the southeastern and southwestern US, and are widely distributed (Harvey et al. 2011). The southern limit of this species is in northern portions of South Carolina, Georgia, Alabama, and Mississippi (Fenton and Barclay 1980). In South Carolina in summer, little brown bats are found primarily in the Blue Ridge mountains, though there have also been a few confirmed reports in the Piedmont, Sandhills and lower Coastal Plain regions (Davis and Rippy 1968). However, it is unknown where most of South Carolina's summer populations overwinter (Bunch et al. 2015*b*).




## Population Status

This species is ranked as Globally Vulnerable (G3), Nationally Vulnerable (N3), and Subnationally Vulnerable (S3?) (NatureServe 2017). However, it is currently ranked as Subnationally Critically Imperiled (S1S2) by the SCDNR Heritage Trust (see Table 2). Yet it is also currently classified as Least Concern (LC) on the IUCN Red List (Arroyo-Cabrales and Álvarez-Castañeda 2008*c*). In South Carolina, the little brown bat is considered rare to locally common in scattered colonies, and is listed as a Highest Priority species in the South Carolina 2015 SWAP (SCDNR 2015), due in part to severe WNS-related mortality.

## General Habitat

Little brown bats are habitat generalists found in a wide variety of ecosystems, likely using most cover types available to them (Barbour and Davis 1969, Fenton and Barclay 1980). However, lakes and streams seem to play a significant factor in habitat use, as much of the foraging activity of this species is associated with aquatic habitats (Fenton and Bell 1979). Little is known about the habitat use and home range of this species in South Carolina.

## Roosts and Roosting Behavior

During summer, adult males and immature females are found in day roosts alone or in small groups away from nurseries (Fenton and Barclay 1980). A variety of roosts are used, including tree cavities, under rocks on hillsides, behind sheets of tarpaper, within log piles, and occasionally in caves in late summer and fall (Fenton and Barclay 1980). Little brown bats often use roosts that provide external heat on southwestern exposures for arousal from daily torpor (Fenton 1970).

Reproductive females choose nursery sites with a relatively high ambient temperature, and are usually located in buildings or hollow trees (Davis and Hitchcock 1965, Youngman 1975, Schowalter et al. 1979). The size of maternity colonies range from around 12 to greater than 1,0000 individuals (van Zyll de Jong 1985, Nagorsen and Brigham 1993). Taller, larger diameter trees in older forest habitat are commonly selected by tree-roosting reproductive females (Kalcounis and Hecker 1996, Crampton and Barclay 1998). Tree-roosting colonies are also known to move frequently between roosts (Crampton and Barclay 1998). In South Carolina, not much is known about the roosting habits of this species. However, summer roosts and maternity colonies have been found in the state in buildings and picnic shelters, such as those at the SCDNR Fish Hatchery in Oconee County (Bunch et al. 2015*b*).

Nursery colonies disperse by midsummer, and swarming activity takes place at hibernacula from around August through October (Fenton and Barclay 1980). It is during this time that different populations of little brown bats mix and are thought to initiate mating relationships, which may ultimately result in the prevention of genetic isolation (Fenton 1969, Carmody et al. 1971). To conserve energy, little brown bats regularly enter torpor. During summer torpor they wake from stimulation of external factors, but while hibernating in winter this species spontaneously arouses from torpor (Menaker 1961).

During winter, both sexes of this species usually hibernate together in caves or mines with high levels of humidity (70-95%) and temperatures above freezing (33.8 to 41°F; 1 to 5°C) (Fenton 1970, Humphrey and Cope 1976, Nagorsen and Brigham 1993). Mines are used more than scattered caves in Ontario, and males comprise over 75% of the population in mines and 65% in caves (Fenton 1970). Depending on torpor arousal frequency and local weather conditions, hibernation lasts from early September through mid-May in the northern portions of its range, or from around November to mid-March in the southern portions (Fenton and Barclay 1980). Little brown bats lose about 25% of their fall weight during hibernation (Fenton 1970). Little brown bats can find roost sites using echolocation calls emitted by others from mating sites within hibernacula (Thomas et al. 1979, Fenton and Barclay 1980). In South Carolina, one hibernacula has been found in a single cave in Pickens County (Bunch et al. 2015*b*). However, not much is known about overwintering habits of the population of little brown bats in the state.
Night roosts are generally located in confined spaces into which groups of bats congregate, and are often located in different places in the same buildings used as day roosts (Barclay 1982). Though the function of night roosts remain unclear, it seems likely that increased roost temperatures are energetically beneficial and may speed up the digestive process (Buchler 1975, Fenton and Barclay 1980).

**Reproduction**
Mating usually occurs one month after the fall onset of swarming, and most females store sperm through the winter months (Thomas et al. 1979). Mating may also occur after females leave hibernation in the spring, happening earlier in the year in the more southerly portions of this species range (Fenton and Barclay 1980). A single pup is born in the spring, which occurs earlier in the year at lower elevations than at higher elevations (Nagorsen and Brigham 1993). Pups are born anywhere from mid-May to August depending on the location (Fenton et al. 1980, Perlmeter 1996). In Kentucky they are born from mid-May to late June (Humphrey and Cope 1976).

Gestation lasts 50 to 60 days, and young begin to fly and are weaned around week three (Wimsatt 1944, Schowalter et al. 1979, Fenton and Barclay 1980). Sexual maturity is reached within the first year in females but most don't breed until the second year, and males reach sexual maturity in their second year (Gustafson and Shemesh 1976, Thomas et al. 1979, Herd and Fenton 1983).

**Food Habits and Foraging**
Little brown bats emerge from their roosts shortly after dusk to feed, with the most activity occurring two to three hours after sunset (Herd and Fenton 1983, Nagorsen and Brigham 1993). With low wing loading, a low aspect ratio, and rounded wing tips, this species is highly maneuverable, and travels around 0.6 to 9 miles (1 to 14 km) from their day roosts to foraging areas (Henry et al. 2002). Little brown bats vary their hunting patterns over an evening. Initially feeding

along margins of lakes and streams and in and out of vegetation 7 to 16 feet (2 to 5 m) above the ground, they later forage 3 to 7 feet (1 to 2 m) over the surface of water in groups (Fenton and Bell 1979). Little brown bats have been found to be most closely associated with riparian zones along streams greater than third-order in the central Appalachians (Ford et al. 2005). Not much is known about the home range or habitat use of this species in South Carolina. However, the activity of little brown bats has been recorded in April, July and October at Keowee Toxaway State Park at Cedar Creek, Lake Jocassee, Stamp Creek marsh, Fall Creek Island, Devils Fork/Howard Creek, the shoreline on Lake Jocassee at Double Spring Mountain west, Thompson River, and the Upper Horsepasture River (Webster 2013).

Aided by their maneuverability, a rapid rate of mastication at seven jaw cycles per second, and relatively quick passage of food through the digestive tract, little brown bats are well adapted to rapidly consuming swarms of small insects (Kallen and Gans 1972, Buchler 1975, Fenton and Bell 1979). This species consumes a wide variety of prey, and selection may be based on size or species depending on the situation (Buchler 1976). In British Columbia, this species fed on Lepidoptera, medium-sized to large Diptera, Neuroptera, and Hymenoptera (Burles et al. 2008). However, little brown bats are known to prey heavily on aquatic insects such as midges, and generally tend to consume insects between 0.11 to 0.39 inches (3 to 10 mm) (Belwood and Fenton 1976, Anthony and Kunz 1977). One-hundred and fifty mosquitoes can be consumed in 15 minutes by little brown bats (Fenton 1983, Tuttle 1988). Little brown bats show a greater variation in diet in the northern portions of its range than the southern portions, potentially due to having less foraging time and a more patchy distribution of prey in the North (Belwood and Fenton 1976, Anthony and Kunz 1977). In South Carolina, however, the diet of the little brown bat is unknown.

**Seasonal Movements**

Between hibernacula and summer roosts, female little brown bats migrate several hundred miles, but not much is known about the seasonal movements of males (Davis and Hitchcock 1965, Fenton 1970, Humphrey and Cope 1976). In the western US, little brown bats are thought to hibernate near their summer range, but in the northeast they may migrate hundreds of miles (Schmidly 1991). It is unknown where most of South Carolina's summer populations spend the winter (Bunch et al. 2015*b*).

**Longevity and Survival**

The longest lifespan of the little brown bat was recorded at 30 years in southeastern Ontario (Keen and Hitchcock 1980), but more commonly live six to seven years old and are often reported at over 10 years old (Humphrey and Cope 1976, Arroyo-Cabrales and Álvarez-Castañeda 2008*c*)(Humphrey and Cope 1976). The mean life expectancy calculated using band recovery data suggest 1.55 years for males and 1.17 to 2.15 years for females, with the first winter of life having the highest mortalities (Humphrey and Cope 1976). The mean annual survival rate calculated by Keen and Hitchcock (1980) was 0.82 for males and 0.71 for females. Survival rates are higher in adults at 63-90% than in juveniles at 23-46% (Frick et al. 2010*b*).

**Threats**

The primary threat to this species is WNS, which has killed at least one million little brown bats from 2006 to 2010 and caused severe declines in abundance in the eastern portion of its range (Frick et al. 2010*a*, Kunz and Reichard 2010). Annual population decrease for bats found at infected hibernacula ranges from 30 to 99% (Frick et al. 2010*a*). The core region where much of the global population of little brown bats occur is now infected with WNS, and threatens to push these core northeastern populations to extinction by 2026 (Frick et al. 2010*a*, Kunz and Reichard 2010).

In many parts of its range, populations of the little brown bat have also declined drastically in part due to pesticides, the loss of roost sites in snags due to deforestation, control measures in nursery colonies, collecting bats for experimentation, and disturbance of individuals during hibernation (Fenton and Barclay 1980, Parker et al. 1996). Mass die-offs at hibernacula not related to WNS have been associated with vandalism and natural disasters such as floods (DeBlase et al. 1965, Gould 1970).

Pesticides cause mortality to this species when applied directly for control purposes, or indirectly to their insect prey (Kunz et al. 1977). Bats may also suffer from a delayed affect from high levels of insecticides released from stored fat deposits metabolized during weaning, migration, and at the end of hibernation (Geluso et al. 1976).

Wind energy is another potential threat to little brown bats, though reported fatalities are much lower than for migratory tree bats. In a study by Johnson et al. (2003), little brown bats were one of six bat species killed at a wind power development at Buffalo Ridge, Minnesota. In a review of bat mortality at wind energy developments in the US by Johnson (2005), little brown bats comprised 5.9% of the total fatalities. No wind turbines have been placed in South Carolina to date, however, Clemson University is constructing a test facility for turbines at the coast (Bunch et al. 2015*b*).

Global climate change is a potential threat to little brown bats because it may make southern hibernation sites unsuitable due to increased temperatures (Bunch et al. 2015*b*).

**Conservation Measures**

Bat exclusion, not extermination, is the most effective and humane way to remove bats from buildings. Sealing out bats and/or adding more light to the roost of a colony are more effective alternatives than use of pesticides for control purposes (Laidlaw and Fenton 1971, Barclay et al. 1980). To minimize negative impacts to little brown bats, eviction from buildings should include appropriately timed exclusion methods. To avoid the maternity period, bats should not be evicted from May through July. Alternatively, populations at the roost area may be decreased by 41 to 96% if lights are introduced to the area (Laidlaw and Fenton 1971). Measures should be taken to provide species-specific alternate roost structures before eviction, and multi-chamber nursery boxes are a reasonable alternative for little brown bats.

Other habitat protection and management recommendations from Bunch et al. (2015*b*) include working to prevent or reduce disturbance to natural and artificial roost structures, as well as to maternity colonies and hibernacula through gating, warning or interpretive signs, prevention of trails or roads to these sites, and other protective measures; designate no-cut buffer zones around known roosts; provide forested corridors between harvested units; and protect foraging areas and migration corridors, which could be done through landowner incentive programs, conservation easements, lease agreements, or purchases. Other measures may include providing, protecting, and maintaining large diameter roost trees, large snags, decadent trees, hollow trees, and roost structures, especially near water or riparian areas; attempting to create or maintain patches of structurally diverse forest in order to provide a wide variety of suitable roosting and maternity sites; minimizing large-scale pesticide use whenever possible; and protecting habitat above or around maternity roosts and known foraging areas from pesticides.

Priority survey and research recommendations from Bunch et al. (2015*b*) include locating hibernacula of little brown bats and monitor winter colonies; conducting demographic studies on this species to measure the effects of WNS if it occurs; monitoring the little brown bat maternity colony at the SCDNR Fish Hatchery in Oconee County; conducting seasonal surveys at caves and mines being considered for closure; and evaluating roost and appropriate food (insects high in polyunsaturated fats) availability, as well as roost temperatures, and compare these factors with winter survival. Further research is greatly needed to identify the best placement of wind turbines, as well as strategies that would minimize impacts to bats (Ellison 2012). The SCDNR Heritage Trust tracks high priority species including the little brown bat, and researchers are requested to submit bat data and occurrence records to their database.

Education and outreach goals recommended by Bunch et al. (2015*b*) include working to create general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans.

# Northern Long-eared Bat (*Myotis septentrionalis*)

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## Description

This medium sized brown bat has short, broad wings well adapted to foraging in clutter (Norberg and Rayner 1987), and is often found in mature forests due to the importance of this habitat for roosting and foraging (Caceres and Pybus 1997). WNS is a substantial threat to northern long-eared bats, as it is linked to mortality of up to 100% in some populations (Blehert et al. 2009). Northern long-eared bats are particularly vulnerable to external threats due to life history traits that make it slow to recover, such as low fecundity (Caceres and Pybus 1997, Caceres and Barclay 2000). In October of 2013 the USFWS proposed a status of Endangered under the ESA for the northern long-eared bat due to threats from WNS. In April of 2015 it was determined this species met the ESA definition of Threatened, and 30 days later the listing became effective with an interim 4(d) rule, later becoming the 4(d) rule, providing flexibility to specific entities who conduct activities in northern long-eared bat habitat (USFWS 2015*a*). This species was found on the SC Coastal Plain (Beaufort County) in 2016.

## Identification

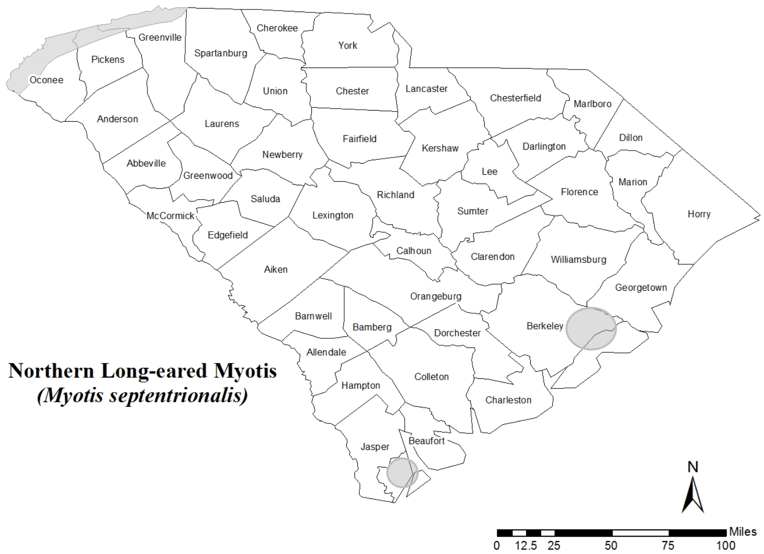
This species weighs 0.2 to 0.3 ounces (6 to 9 gr) and has a wingspan of 9 to 10 inches (23 to 26 cm) (Harvey et al. 2011). Its pelage is light brown to gray brown on the dorsum, and pale grayish brown to pale brown below. The ears and membranes of the wing and tail are slightly darker brown than the dorsal pelage. The ears are narrow and pointed, and the long tragus is pointed. When the ears are gently pressed forward, they reach beyond the tip of the nostrils. The calcar may either be slightly keeled or the keel may appear to be lacking (Trani et al. 2007). Females tend to be heavier than males (Caire et al. 1979, Williams and Findley 1979). The northern long-eared bat resembles other *Myotis* species, but misidentification is avoided by the identification of the long, pointed tragus and ears that extend more than 2 mm beyond the tip of the nose (Menzel et al. 2002*c*). Additionally, this species has a faint black mask, longer rostrum, missing hair around the eyes, and is generally smaller than the little brown bat.

## Taxonomy

The northern long-eared bat is considered monotypic (Wilson and Reeder 2005).

## Distribution

Northern long-eared bats are widely but patchily distributed across eastern North America ranging from southern Canada and the central and eastern US, northwest to the Dakotas, west through the central states, and south to northern Florida. Historically, this species was more common in the northern portion of the range than the southern and western portions (Amelon and Burhans 2006*a*), and is still relatively uncommon in most of the South (Barbour and Davis 1969,




**Northern Long-eared Myotis**
***(Myotis septentrionalis)***

Sealander and Heidt 1990). In South Carolina, northern long-eared bats used to be found primarily in the Blue Ridge mountains where they had once been considered common. There have also been a few confirmed reports in the Coastal Plain of North Carolina (Grider et al. 2016). Then in November 2016, two individuals were discovered on the Coastal Plain of South Carolina in Beaufort County, and another nine individuals were found breeding in Berkeley and Charleston counites in June and July of 2017. Currently, the USFWS considers the range of the northern long-eared bat to be more extensive than our SC map, as seen in its WNS Buffer Zone map (Figure 6; https://www.fws.gov/midwest/endangered/mammals/nleb/pdf/WNSBufferZone.pdf), and includes the following South Carolina counties: Abbeville, Anderson, Beaufort, Berkeley, Charleston, Cherokee, Colleton, Dorchester, Florence, Georgetown, Greenville, Hampton, Horry, Jasper, Laurens, Marion, Oconee, Pickens, Spartanburg, Union, Willamsburg and York.

**Population Status**

Common over much of its range, this species has a rounded status of Critically Imperiled both Globally (G1G2), and Nationally (N1N2), and Subnationally Apparently Secure (S4) (NatureServe 2017). However, it is currently ranked as Subnationally Critically Imperiled (S1) by the SCDNR Heritage Trust (see Table 2). It is classified as Least Concern (LC) on the IUCN Red List (Arroyo-Cabrales and Álvarez-Castañeda 2008*d*). However, the northern long-eared bat is currently listed as federally threatened (USFWS 2015*a*), athough it is under consideration for an uplisting. In South Carolina the northern long-eared bat is generally considered rare, is listed as a Highest Priority species in the South Carolina 2015 SWAP, and because of the federal threatened listing is now considered state threatened (SCDNR 2015).

**General Habitat**

Northern long-eared bats are often found in mature forests due to the importance of this habitat for roosting and foraging (Caceres and Pybus 1997), and may prefer old-growth with intact interior and low edge-to-interior ratios (NatureServe 2017). However, this species is also found in a variety of habitats including mature second-growth eastern deciduous forests, clearcuts, deferment harvests, streams, and road corridors (M. A. Menzel et al. 2003). In South Carolina, sparse vegetation and mature tree stands were found to be the best predictor of foraging habitat use by northern long-eared bats (Loeb and O'Keefe 2006).

**Roosts and Roosting Behavior**

Northern long-eared bats have been found roosting in tree cavities (Owen et al. 2001, Menzel et al. 2002*d*), under the bark of trees (Mumford and Cope 1964), in buildings (Doutt et al. 1966, Turner 1974), behind shutters (Mumford 1969), storm sewers (Goehring 1954), and in caves, mines, and crevices in rock outcrops (Harvey et al. 1999*a*, *b*). In a Arkansas study, 85% of male and 95% of female roosts were found in snags, most of which had a 10 to 25 cm dbh (Perry and Thill 2007*b*). The wide range of tree species chosen as roost sites across the range of northern long-eared bat shows opportunistic selection at the microhabitat scale when it comes to roost-sites (Foster and Kurta 1999, Cryan et al. 2001). In Illinois, the average roost height for this species was 30 feet (9 m) (Carter and Feldhamer 2005).

During summer, males and non-reproductive females roost separately, either singly or in small groups of less than 10 in trees, buildings, and caves (Turner 1974, Nagorsen and Nash 1984, Nagorsen and Brigham 1993). Males tend to choose roosting sites in live-damaged trees with a relatively small diameter (Lacki and Schwierjohann 2001, Perry and Thill 2007*b*, O'Keefe 2009). Males and non-reproductive females also use night roosts located in caves, mines, and quarry tunnels, which differ from day roost habitats (Jones et al. 1967, Clark et al. 1987). In South Carolina during summer, a northern long-eared bat was tracked to a location under the loose bark of a dead pine near National Forest land in Oconee County (Bunch and Dye 1999*b*). According to the USFWS (2015*b*), potential suitable summer habitat for northern long-eared bats may include live trees and/or snags with a dbh greater than or equal to 3 inches (7.62 cm) that have cavities, crevices, exfoliating bark, and/or cracks, and are within 1,000 feet (305 m) of forested habitat. In addition, wooded corridors and human-made structures should also be considered potential suitable summer habitat. However, summer roosting habits in South Carolina are not well known.

Maternity colonies of 30 to 60 individuals generally roost in trees, tree cavities, under bark, under shingles, and in buildings (Foster and Kurta 1999, Caceres and Barclay 2000, Whitaker and Mumford 2009). In the southern Appalachian Mountains, maternity colonies of 75 were found in northern red oaks with a dbh of > 16.5 inches (42 cm) and approximately 150-200 years old. Regardless of geographic location, warm sites are selected in order to maximize the growth of young (Amelon and Burhans 2006*a*). Studies show females in maternity colonies prefer roosts in tall hardwood trees in early stages of decay (Sasse and Pekins 1996, Caceres 1998), in live trees with less canopy closure (Caceres 1998, O'Keefe 2009), and in large diameter trees (Sasse and Pekins 1996, Foster and Kurta 1999, O'Keefe 2009). However, Owen et al. (2001) found that selected roosts in West Virginia were in taller, smaller diameter trees, surrounded by more live overstory trees and snags, and surrounded by a higher basal area of other snags. Tree colony sites occupied in Canada had more mature, shade-tolerant deciduous tree stands than summer roosts occupied by males in conifer-dominated stands (Broders et al. 2006). Maternity roosts were also found to be associated with upper and mid slopes in Kentucky (Lacki and Schwierjohann 2001). Additionally, females within the colony may frequently switch roost trees, and roost site selection may vary depending on reproductive stage. For example, during lactation females may switch roost trees every two to five days and roost higher in trees located in areas of relatively less canopy cover and tree density compared to pre- and post- lactation stages

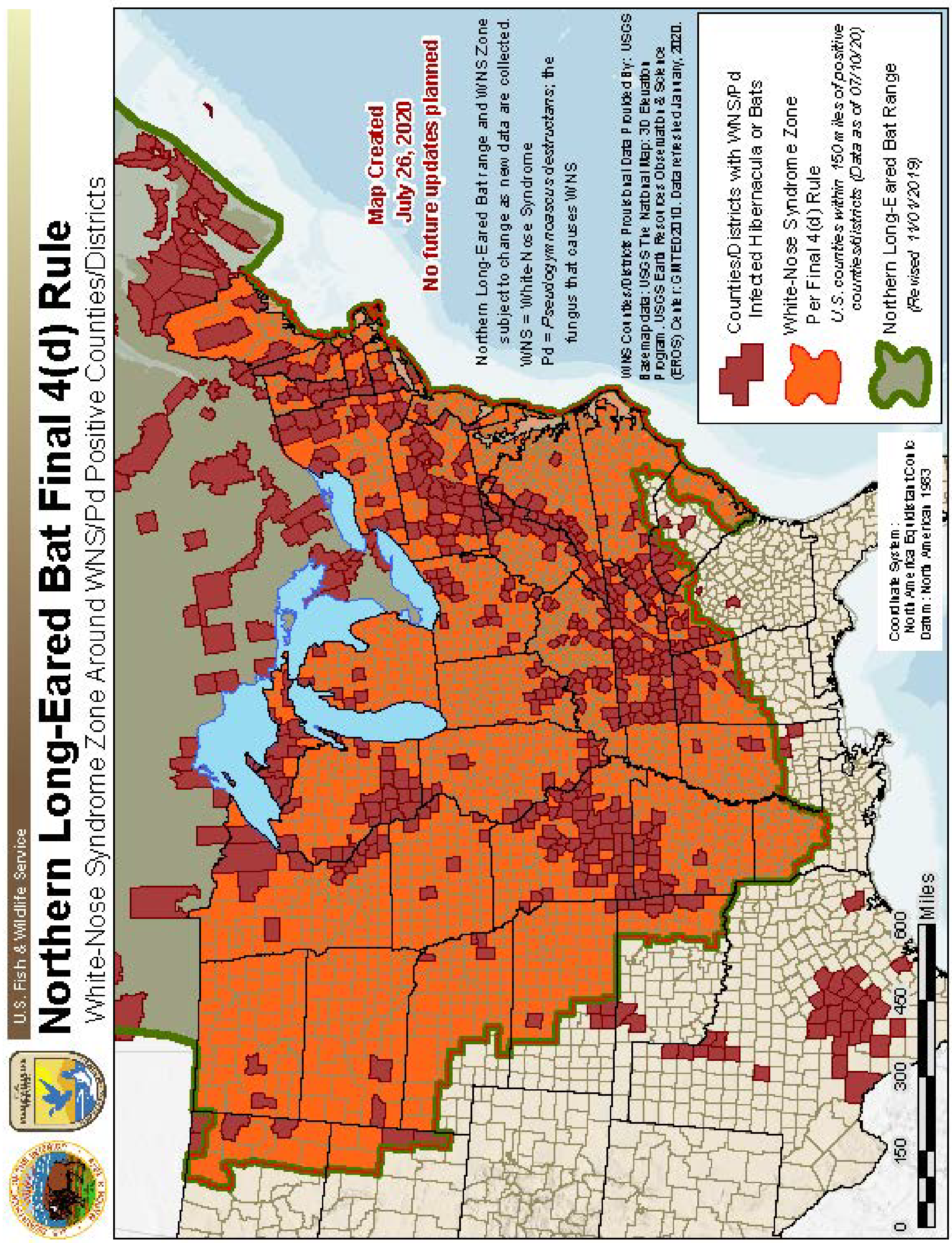



Figure 6: USFWS northern long-eared bat range map with WNS 150-mile buffer zone.*
http://www.fws.gov/midwest/endangered/mammals/nleb/pdf/WNSBufferZone.pdf

(Foster and Kurta 1999, Garroway and Broders 2008). Maternity colony size has been shown to decline as summer progresses, with the largest colonies for pregnant females, medium-sized colonies used by lactating females, and smaller colonies used by post-lactating females (Lacki and Schwierjohann 2001). Females return to their natal sites annually (Arnold 2007). Maternity colony habits in South Carolina are unknown.

During late fall and winter (around October through April), northern long-eared bats hibernate either singly or in small groups rarely exceeding 100 individuals (Amelon and Burhans 2006*a*), though they can include 350 individuals (Hitchcock 1949, Heath et al. 1986). They may be found with large numbers of other species of bats, including the big brown bat, little brown bat, and tricolored bat (Hitchcock 1949, Mills 1971, Caire et al. 1979). This species may hibernate for up to nine months in the northern part of its range (Stones and Frum 1969), and by the end of winter have lost 41 to 45% of the fat stores gained prior to hibernation (Caire et al. 1979, Caceres and Barclay 2000). This species is commonly found in the crevices on walls or ceilings (Caire et al. 1979, Whitaker and Gummer 2001) of hibernacula that include caves, mines, storm sewers, and crevices in rock outcrops (Goehring 1954, Harvey et al. 1999*a*, *b*). Preferred sites have high humidity and consistent low temperatures (Fitch and Shump 1979, Whitaker and Mumford 2009). Northern long-eared bats are known to wake from torpor on warm winter nights, change locations within the hibernacula, or fly outside the hibernacula (Whitaker and Rissler 1992*a*, Whitaker and Mumford 2009). Relatively high fidelity to hibernacula has been recorded in this species. In a study conducted by Griffin (1945), for every bat recaptured elsewhere, 100 bats were observed returning to their cave of origin over subsequent winters. In other studies, 5% of the original banded population (which can be over 90% of recaptured individuals) were subsequently recaptured at the same hibernacula the following fall (Mills 1971, Caire et al. 1979). In South Carolina, northern long-eared bats have been detected at two known hibernacula: 26 individuals were found in a cave in 1995 (which has not been surveyed since), and one individual was found in a tunnel in 2011 (Bunch et al. 1998*a*, Bunch 2011). However, the winter roosting habits for this species are not well known in the state.

**Reproduction**

Mating begins from late July in the northern portion of this species' range to late August in the southern portion, and completes by September and October (Amelon and Burhans 2006*a*). Sperm is probably stored in the female's uterus until spring when fertilization takes place, though breeding activity may extend into spring (Racey 1982). In northern areas, females leave hibernacula starting in May with peak numbers leaving in late June, and in southern areas females leave hibernacula starting in March with peak numbers leaving in May (Amelon and Burhans 2006*a*). A single pup is usually born between mid-May and mid-June in the southeastern portions of its range, but may be as late as mid-July in the more northern portions (Caceres and Barclay 2000). Recently, a population of northern long-eared bats on the coast of South Carolina were estimated to give birth between late April and early May. This estimation is one month earlier than what is included in the current 4(d) rule and what was previously known (Kindel 2019). Gestation lasts 50 to 60 days (Baker 1983), young begin to fly at three weeks (Kunz 1971, Feldhamer et al. 2001), and lactation lasts around 30 days (Ollendorff 2002). Male and female young may mate their first fall, but details are unknown (NatureServe 2017). The reproductive habits of the northern long-eared bat are unknown in South Carolina.

**Food Habits and Foraging**

Emerging to forage at dusk, the northern long-eared bat has peaks of foraging activity one to two hours after sunset and seven to eight hours after sunset (Barbour and Davis 1969, Kunz 1973). This species is considered a clutter-adapted species and often forages in densely forested areas (Norberg and Rayner 1987). With a rounded wing tip and relatively low aspect ratio of 5.8 and wing loading of 6.8 (Norberg and Rayner 1987), the northern long-eared bat has a relatively slow, maneuverable flight well adapted to a gleaning foraging strategy in canopy gaps and forested areas with open understories where prey is consumed off of foliage while feeding (Amelon and Burhans 2006*a*). Mature, intact forests are an important habitat for roosting and foraging areas in this species (Caceres and Pybus 1997, Patriquin and Barclay 2003, Loeb and O'Keefe 2006, Perry and Thill 2007*b*). However, high post-harvest occupancy of northern long-eared bats in newly cut areas of national forest in North Carolina has been observed (O'Keefe et al. 2013). They may also utilize foraging areas in trees among hillsides and ridges (LaVal et al. 1977); along stream corridors, in adjacent agricultural lands and floodplains and in mature deciduous uplands (Kunz 1973, 1971); over ponds (Cowan and Guiguet 1965, Brack Jr. and Whitaker 2001); and on the ground (Kirkland 1997). Foraging home ranges for females have been reported in West Virginia at an average of 150 acres (61.1 ha) (Menzel et al. 1999*b*). Reproductive females have been shown to travel an average of around 2,000 feet (602 m) from maternity roosts to foraging areas (Sasse and Pekins 1996).

As an opportunistic insectivore, the northern long-eared bats feeds on Araneae, Lepidoptera, Coleoptera, Trichoptera, Diptera, and Plecoptera (Whitaker 1972, Belwood 1979, LaVal and LaVal 1980) with spiders, moth and butterfly larvae composing 12.7% of stomach contents (Brack Jr. and Whitaker 2001). In more than 50% of fecal pellet samples taken from individuals in the central Appalachians, Coleoptera, Lepidoptera, and Neuroptera fragments were found (Griffith and Gates 1985). Though geographic location, season, and individual preference may contribute to a varying diet in this species (Whitaker 1972, Caceres 1998), foraging habits for this species are unknown in South Carolina.

**Seasonal Movements**

Despite recent research interest in this species, there is still debate on whether Northern long-eared bats are considered migratory. The winter and summer ranges of northern long-eared bats have been reported to be the same (Barbour and Davis 1969), while some populations have been documented moving seasonally. In some cases, populations may travel up to 35 miles (56 km) between hibernacula and summer habitat (Caire et al. 1979). Movements between February and April have also been reported, with an individual traveling 60 miles (97 km) between caves (Griffin 1940).

**Longevity and Survival**

The longest life span recorded of a northern long-eared bat was 18.5 years old (Hall et al. 1957).

**Threats**

Northern long-eared bats are particularly vulnerable to external threats due to life history traits that make it slow to recover, such as low fecundity (Caceres and Pybus 1997, Caceres and Barclay 2000).

WNS is a substantial threat to northern long-eared bats, as it is linked to mortality of up to 100% in some populations (Blehert et al.

2009). Mortality has occurred across portions of its range (Gargas et al. 2009), and threatens to impact significant portions in the near future. According to Frick et al. (2015), there has been a loss of 69% of the northern long-eared bat's former hibernacula.

A ten-fold decrease in the numbers of bats in North American hibernacula has been attributed to WNS, and significant local extinctions in many species have resulted, including up to 69% of former hibernacula of the now federally threatened northern long-eared bat (Frick et al. 2015).

According to Alves et al. (2014), an expected relative population reduction for this species is estimated to be 31.3% in an intermediate population-reduction scenario, compared to a pessimistic scenario of 42.4%, and an optimistic scenario of 12.9% population reduction. In the event of pessimistic and intermediate scenarios, this species will be considered Vulnerable.

Habitat fragmentation through various activities may reduce occupancy of this species in forested habitat due to increased edge habitat (Yates and Muzika 2006).

Deforestation is a threat to this species as it causes direct loss of roosting and foraging habitats and changes insect abundance and distribution (Hayes and Loeb 2007). Because mature forest stands are important habitat for northern long-eared bats (Caceres and Pybus 1997), even-age timber management practices could have an adverse effect on this species. Additionally, oil, gas, and mineral development activities may also negatively impact northern long-eared bats through alternation or removal of mature forested habitats (USFWS 2011).

Wind energy development threatens this species through some mortality from the facilities themselves (Kerns and Kerlinger 2004, Johnson 2005), as well as through potential clearing of mature forests for turbines and road construction. No wind turbines have been placed in South Carolina to date, however, Clemson University is constructing a test facility for turbines at the coast (Bunch et al. 2015*b*).

Disturbance and vandalism of hibernacula by human activities poses a great threat to this species (Tuttle 1979, Thomas et al. 1990, Caceres and Pybus 1997). Along with disturbance during maternity periods, these threats are a significant factor in the widespread decline of species dependent on caves and mines (Amelon and Burhans 2006*a*). The energy demands made on hibernating northern long-eared bats may be increased from repeated arousal due to human disturbance, forcing northern long-eared bats to burn critical fat reserves (Caceres and Pybus 1997). This loss of energy stores may affect overwinter viability, and in addition, may cause lower reproductive rates since females may become significantly lighter in weight during the reproductive period (Reichard and Kunz 2009). Destruction of hibernacula is the main factor in population declines of bat species dependent on caves and mines (Humphrey 1978, Sheffield and Chapman 1992). Mine closures cause direct mortality to this species if they occur during hibernation. Closing mines during non-hibernating periods may force northern long-eared bats to burn critical fat reserves while searching for new hibernacula (USFWS 2011).

Another threat to northern long-eared bats is the inadequacy of existing regulations for management of forestry, wind energy development, and oil, gas, and mineral extraction, especially when it comes to the protections afforded a state-listed species. These protections are meant to prevent trade or possession of state-listed species, but do not protect against habitat destruction (USFWS 2011).

Global climate change is also a potential threat to this species because it may make southern hibernation sites unsuitable due to increased temperatures (Bunch et al. 2015*b*).

**Conservation Measures**

Bat exclusion, not extermination, is the most effective and humane way to remove bats from buildings. Sealing out bats and/or adding more light to the roost of a colony are more effective alternatives than use of pesticides for control purposes (Laidlaw and Fenton 1971, Barclay et al. 1980). Northern long-eared bats do not typically use buildings, but to minimize negative impacts to this species when they do, eviction from buildings should include appropriately timed exclusion methods. To avoid the maternity period, bats should not be evicted from May through July. Alternatively, populations at the roost area may be decreased by 41 to 96% if lights are introduced to the area (Laidlaw and Fenton 1971). Measures should be taken to provide species-specific alternate roost structures in the event of a disturbance, and multi-chamber nursery boxes may work for northern long-eared bat colonies (though evidence is currently lacking).

Since roost sites for this species at various life stages have been found in a wide range of live trees and snags in all size classes, best forest management practices would allow for diversity in tree species, snag conditions, and size classes (Lacki and Schwierjohann 2001, Menzel et al. 2002*d*, Ford et al. 2006*b*). Mature forest stands are important roosting and foraging habitat for northern long-eared bats (Caceres and Pybus 1997), so avoiding even-age timber management practices and keeping contiguous tracts of mature forest would provide the best habitat for this species. Maintaining closed forest conditions will also benefit northern long-eared bats since they often forage in closed upland forest and intact forest stands (Owen et al. 2003, Ford et al. 2005). Protecting or managing for potential summer roost habitat such as live trees and/or snags with a dbh greater than or equal to 3 inches (7.62 cm) that have cavities, crevices, exfoliating bark, and/or cracks and are within 1,000 feet (305 m) of forested habitat (USFWS 2015*b*) may benefit this species. Managing for wooded corridors and conducting surveys for this species in human-made structures could also be beneficial as they are considered suitable summer roosting habitat as well (USFWS 2015*b*).

Recommendations from NatureServe (2015) state that caves and mines that serve as hibernacula should be protected from October through April, and include a buffer zone to protect from disturbances such as logging that might change water and air flow, temperature, and humidity. Additionally, maternity colony roosts and surrounding habitat should be protected during late spring and early summer, with adjacent foraging areas protected from deforestation.

Other habitat protection and management recommendations from Bunch et al. (2015*b*) include working to prevent or reduce disturbance to natural and artificial roost structures, as well as to maternity colonies and hibernacula through gating, warning or interpretive signs, prevention of trails or roads to these sites, and other protective measures; designate no-cut buffer zones around known roosts; provide forested corridors between harvested units; and protect foraging areas and migration corridors, which could be done through landowner incentive programs, conservation easements, lease agreements, or purchases. Other measures may include providing, protecting, and maintaining large diameter roost trees, large snags, decadent trees, hollow trees, and roost structures, especially near water or riparian areas; attempting to maintain intact, mature forest stands; minimizing large-scale pesticide use whenever possible; and protecting habitat above or around maternity roosts and known foraging areas from pesticides.

Priority survey and research recommendations from Bunch et al. (2015*b*) include locating hibernacula for this species in the state; conducting seasonal surveys at caves and mines being considered for closure; and evaluating roost and appropriate food (insects high in polyunsaturated fats) availability, as well as roost temperatures, and compare these factors with winter survival. Further research is greatly needed to identify the best placement of wind turbines, as well as strategies that would minimize impacts to bats (Ellison 2012). The SCDNR Heritage Trust tracks high priority species including the northern long-eared bat, and researchers are requested to submit bat data and occurrence records to their database.

Education and outreach goals recommended by Bunch et al. (2015*b*) include working to create general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans.

# Northern Yellow Bat (*Lasiurus intermedius*)

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## Description

The northern yellow bat is the second largest bat in South Carolina, but one of the least known mammalian species in the state. Spanish moss (*Tillandsia usneoides*) is a preferred roosting site of northern yellow bats, and the distribution of this species is therefore closely associated with the range of Spanish moss (Barbour and Davis 1969). Northern yellow bats differ from other tree roosting species such as eastern red bats in that only the dorsal surface of the uropatagium is furred, there are no white patches on the shoulders or wrists, and the ears are more pointed. This species is also more social and may form colonies during the nursing season (Reid 1997). Very little is known about northern yellow bats compared to other North American bat species, and it is the least understood mammalian species in South Carolina (Bunch et al. 2015*c*).

## Identification

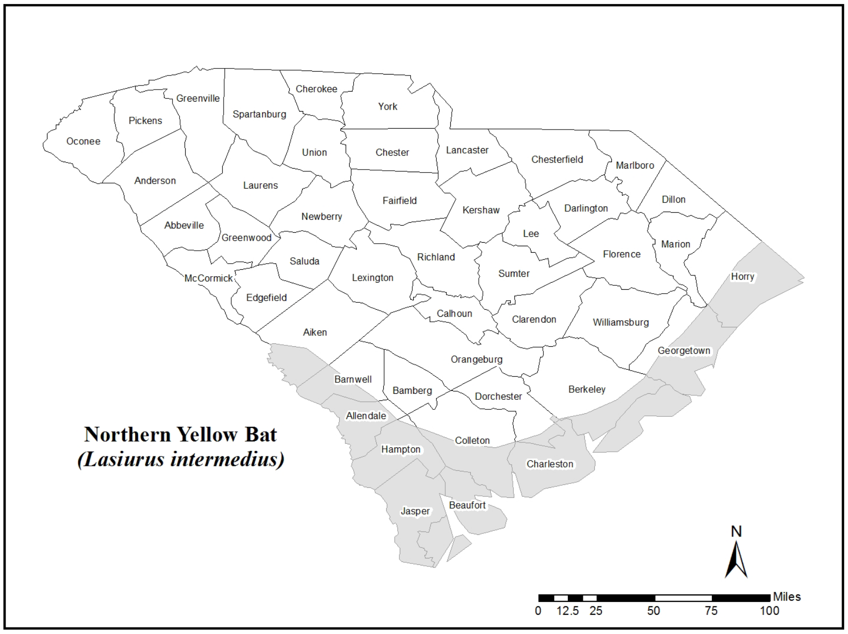
The northern yellow bat weighs 0.5 to 1.1 ounces (14 to 31 gr) and has a wingspan of 14 to 15 inches (35 to 39 cm) (Harvey et al. 2011). The pelage is long and silky, and varies from yellow-orange to yellow-brown and is faintly washed with brown or gray above, and light yellow below. The dorsal surface of the uropatagium is furred on the basal third or half, unlike other *Lasiurus* species whose uropatagium is also furred on the ventral surface. Females have four mammae and tend to be larger than males. The wing membranes are brownish, and the calcar is slightly keeled. The ears are relatively short and rounded, though they are considered more pointed than other tree roosting species (Webster et al. 1980).

## Taxonomy

Currently there are two recognized subspecies (Wilson and Reeder 2005) of the northern yellow bat, though this has been debated in the past (Whitaker and Hamilton 1998). However, only *Lasiurus intermedius floridanus* has been confirmed in South Carolina. Note that a molecular study in 2015 reassessed the evolutionary relationships of tree bats of the genus Lasiurus, recommending the recognition of 3 separate genera: Lasiurus (red bats), Dasypterus (yellow bats), and Aeorestes (hoary bats) (Baird et al. 2015). Thus the taxonomy of this species may also be recognized as *Dasypterus intermedius*.

## Distribution

The distribution of the northern yellow bat is poorly known, but is thought to be restricted to the coastal areas of the southeastern US and southward into Central America (Webster et al. 1980). In the US this species has been found as far north as coastal New Jersey (Koopman 1965), though it was presumed to be an accidental occurrence, and in Virginia. The range extends south to the Coastal Plain of Georgia and Alabama and into Florida, and west along the coast to south-central Texas




and southward into eastern Mexico (Webster et al. 1980). In South Carolina, this species is found in the Lower Coastal Plain and into the Upper Coastal Plain along the Savannah River (Bunch et al. 2015*c*).

**Population Status**
Density and population estimates for northern yellow bats are unknown across its range, and are not available for South Carolina. This species is generally considered to be rare except in central Florida where it is the most abundant bat (Humphrey 1992), this species is not assessed adequately elsewhere due to lack of information. Its rank is Globally Secure (G5), Nationally Apparently Secure (N4), and is Subnationally Unranked (SNR) (NatureServe 2017). It is currently classified as Least Concern (LC) on the IUCN Red List (Miller and Rodriguez 2008). This species is listed as a Highest Priority species in the South Carolina 2015 SWAP (SCDNR 2015), due in part to the lack of information about northern yellow bats and the severe WNS-related mortality occurring in other bat species.

**General Habitat**
Northern yellow bats are generally associated with Spanish moss or palm trees in coastal habitats of the southeastern US, and typically found in wooded areas near permanent water (Webster et al. 1980). They are also found in lowland prairie, marsh, and wooded habitats of Texas (Schmidly 1991), as well as dry upland sites in the central peninsula of Florida and throughout the state (Sherman 1944, Jennings 1958, Humphrey 1992).

**Roosts and Roosting Behavior**
During summer, northern yellow bats usually roost alone and have been found in Spanish moss in live oaks (*Quercus virginiana*) in Georgia and Florida (Jennings 1958, Menzel et al. 1995, Coleman et al. 2012), in pine-oak woodlands in Florida and Mexico (Sherman 1944, Jones 1964, Carter and Jones 1978), in the grooves of palm trees in Texas (Davis 1974), and on the stems of hardwoods in Virginia (Rageot 1955). Usually this species doesn't use buildings, but Koopman (1965) reported one specimen found in a garage. Though a solitary rooster, individuals of this species are known to aggregate into the same tree (Jennings 1958). No studies have been conducted on the summer roosting habits of northern yellow bats in South Carolina.

There has been evidence that maternity roosts form during the nursing season. In July in Catamaco, Veracruz, a communal roost of 45 individuals with lactating females and smaller individuals with unworn teeth (potentially young of the year) were reported flying out from under corn stalks hanging from the side of an old tobacco-curing shed (Baker and

Dickerman 1956). From June through August, adult females and young have been found in feeding and roosting groups (Barbour and Davis 1969, Davis 1974).
The winter roosting habits of the northern yellow bat are not well known, and there haven't been any studies investigating those habits in South Carolina. There have been records of northern yellow bats in January in South Carolina (Golley 1966), suggesting they may overwinter in the state. Since this species may become torpid when exposed to cold temperatures (Rageot 1955), it is possible that the northern yellow bat might hibernate during winter in the northern portions of its range in Virginia and North Carolina where they may be considered a resident (Lee et al. 1982, Linzey 1998). However, northern yellow bats are also known to forage on warm nights elsewhere during this time (Jennings 1958). Sexual segregation occurs during winter, and in Florida, males may congregate during this time (Barbour and Davis 1969).

**Reproduction**
Reproduction and the extent of the mating season are not completely understood for the northern yellow bat. It is thought that mating occurs in the fall and winter, and sperm is stored in the female's uterus until spring when fertilization takes place (Hall and Jones 1961, Barbour and Davis 1969). Two to four pups (average of 3.4 in Florida) are born in late May and June (Jennings 1958, Barbour and Davis 1969). Young are thought to begin to fly in June or July in Texas, Louisiana, and Veracruz (Webster et al. 1980). The reproductive habits of the northern yellow bat are not known in South Carolina.

**Food Habits and Foraging**
Northern yellow bats are known to leave their roosts well before dark to forage (Lowery 1974). Considered a high-flying bat, this species forages 16 to 23 feet (5 to 7 m) above the ground (Barbour and Davis 1969, Schmidly 1983) in open areas such as golf courses, airports, and fields (Jennings 1958); in croplands, marshes, lake margins, and forest openings (Zinn 1977, Schmidly 1983, Krishon et al. 1997); and over piles of sawdust in Florida (Moore 1949). According to Krishon et al. (1997), the average distance of one northern yellow bat from its roost to its foraging location was 358 feet (109 m). The home range recorded for this bat was 26 acres (10.5 ha), and was located in oak habitat most of the time (73%), but was also found in loblolly and slash pine (25%) communities.

In mid to late summer in Florida, groups of young bats (mostly females) collect in feeding aggregations of greater than 100 individuals (Jennings 1958). According to a few samples, northern yellow bats have been found to feed on Coleoptera, Diptera, Homoptera, Hymenoptera, Odonata, and Zygotera (Sherman 1939, Zinn 1977). From two bats captured on Sapelo Island, Georgia, 69% of the fecal pellets were composed of Hymenoptera and 31% were Coleoptera (Carter et al. 1998). In Florida, individuals were found hunting flies and mosquitoes among beaches and dunes (Ivey 1959).

During winter, northern yellow bats are known to forage on warm nights (Jennings 1958). No foraging habits, home range or habitat use studies of northern yellow bats have been conducted in South Carolina.

**Seasonal Movements**
Little is known about the migration patterns of this species. Northern yellow bats may either migrate or hibernate in areas where they have been reported year round, such as in Florida (Jennings 1958) and southern Louisiana (Lowery 1974). In eastern Texas they may migrate during winter (Schmidly 1983), but in southeastern Virginia and the

Coastal Plains of North Carolina they may be resident (Lee et al. 1982, Linzey 1998).

**Longevity and Survival**
No longevity records exist for northern yellow bats. However, due to the fact this species can have litters of three, it may live for a relatively short time compared to other bat species (Texas Parks and Wildlife Department 1994).

**Threats**
Threats are difficult to assess for this species because so little is known about density and population estimates, foraging habits, home range or habitat use for northern yellow bats.

Habitat and roost site loss due to development and removal of palm fronds are threats to this species (Bunch et al. 2015*c*). Residential development and citrus grove plantations may threaten this species if they result in the loss of sandhill and oak hammock habitats (Humphrey 1992). The harvesting of Spanish moss may still be a threat in some areas, but the development of synthetic materials replacing the need for Spanish moss may have reduced this threat (Trani et al. 2007). The loss of Spanish moss due to a fungal infection such as the outbreak seen during the 1960's where Spanish moss was eliminated from many areas of central Florida (Smith and Wood 1975, Jensen 1982) is a potential threat.

Pesticide poisoning, especially by organochlorines and anticholinestrase, is a threat to northern yellow bats because it has been shown to cause population declines in insectivorous bats (Geluso et al. 1976, Reidinger 1976, Brady et al. 1982). Pesticides can also alter behavior, cause mortality, and be transferred to nursing young (Clark 1981, 1986, Henny et al. 1982).

Natural causes such as hurricanes may also lead to loss of habitat as well as direct mortality (Bunch et al. 2015*c*). Deforestation of oak (*Quercus* species) from Sudden Oak Death (SOD) disease caused by the plant pathogen *Phytophthora ramorum* may pose a threat to habitats critical to forest-dwelling bats. Though it has not been found in a natural setting to date, this disease was recently detected on nursery stock in South Carolina in South Carolina (Bunch et al. 2015*b*).

Collisions with wind turbines or injury from active turbines (Erickson et al. 2002, Tuttle 2004), as well as collisions with towers may also be potential threats to this species (Crawford and Baker 1981).

**Conservation Measures**
Wind turbines are a relatively new threat, and thus very little research has been conducted on how to minimize the dangers of turbines to bats. What is known is that the new larger, taller turbines have decreased mortality in birds but actually increased bat fatalities (Barclay et al. 2007), and that facilities built on ridge tops appear to have the highest bat fatalities (Johnson and Erickson 2008). Research is greatly needed to identify the best placement of turbines, as well as strategies that would minimize impacts to bats (Ellison 2012). Wind turbine management recommendations from Bunch et al. (2015*c*) include working with wind energy development companies to mitigate the impacts of wind turbines, such as increasing the cut-in speed of turbines to reduce mortalities; and establishing timing and location of potential wind-energy conflicts through pre-construction surveys and determine potential mitigation measures to reduce mortality to northern yellow bats. Also, using flashing lights instead of constant lights on towers, which is now regarded as acceptable by the FAA, can reduce bat mortality (Bunch et al. 2015*a*).

Other habitat protection and management recommendations from Bunch et al. (2015*c*) include working to retain Spanish moss and old palm fronds on public lands to benefit northern yellow bats; encourage retention of Spanish moss and old palm fronds on private lands to benefit northern yellow bats; protect roosting areas in Spanish moss habitat; avoid removal of old palm fronds in spring when young of the year are present; work with developers and citrus grove owners to determine potential mitigation measures that minimize roost loss in sandhill and oak hammock habitats; minimize bat mortality during prescribed burn activities by burning in the spring or summer; advise forestry professionals to conduct controlled burns when minimum night temperatures are > 39°F (4°C) and temperatures at the time of ignition are > 50°F (10°C); and timber management in the Piedmont region that creates uncluttered forest, such as pine thinning or controlled burns may benefit this species by creating more open forest areas. Minimize or carefully consider large-scale pesticide use whenever possible. Other measures may include working to minimize or carefully consider large-scale pesticide use whenever possible, and protect habitat above or around maternity roosts and known foraging areas from pesticides.

Priority survey and research recommendations from Bunch et al. (2015*c*) include conducting further research to identify priority areas for field surveys of northern yellow bats; determine the distribution of this species in the Carolinas through surveys; locate northern yellow bat roosts through survey efforts and monitor those sites for use over time; conduct molecular research to determine variation within the species across its known distribution, and validate the yellow bat subspecies designation; conduct pesticide and/or heavy metal research to determine if, and how severely, northern yellow bats are affected; determine summer and winter roost site and habitat requirements for this species; determine the extent of off-shore foraging and commuting and its seasonality to assess vulnerability of northern yellow bats to off-shore wind development; and determine the vulnerability of this species, especially during fall migration, to coastal wind energy development. The SCDNR Heritage Trust tracks high priority species including the northern yellow bat, and researchers are requested to submit bat data and occurrence records to their database.

Education and outreach goals recommended by Bunch et al. (2015*c*) include creating general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans; discourage the practice of removing roosting habitat such as old palm fronds and large amounts of Spanish moss from trees; create demonstration areas on publicly owned land by placing prominent signage in highly visible areas with old fronds left uncut that explain how old fronds provide important roosting habitat for northern yellow bats.

# Rafinesque's Big-eared Bat (*Corynorhinus rafinesquii*)

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## Description

An endemic to bottomland hardwood forests of South Carolina's Coastal Plain, the Rafinesque's big-eared bat has the longest ears of all bat species found in the state. Rafinesque's big-eared bats eat destructive moth larvae pests, disease-transmitting flies, and horse and deer flies (Ellis 1993, Lacki and LaDeur 2001). Though populations of this bat are not currently large enough to have a large impact (Whitaker and Hamilton 1998) they are still a main predator of these insect species. Unfortunately, loss and degradation of bottomland hardwood forest habitat has likely been a long-time driving factor contributing to the limited populations and vulnerability of Rafinesque's big-eared bats (Tiner 1984, Clark 2000, Mitsch and Gosselink 2001).

## Identification

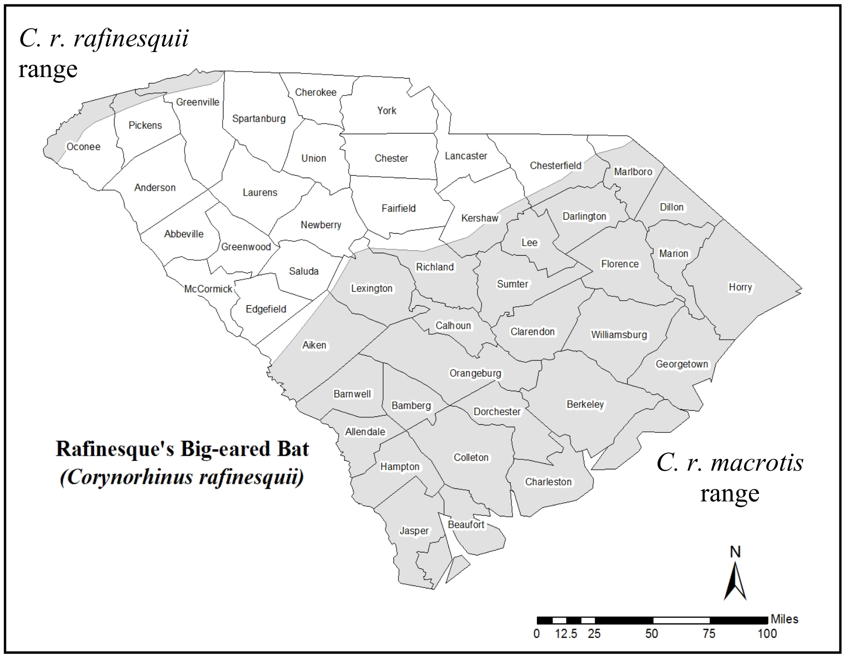
Rafinesque's big-eared bat is a medium sized bat with ears that measure 1.5 inches long. The ears are often coiled alongside the head during torpor, and take a few minutes to uncoil (inflate) when bats are disturbed (Jones 1977). Another distinctive feature of this species are the facial glands located on either side of the nose. Rafinesque's big-eared bats weigh 0.3 to 0.5 ounces (8 to 14 gr) and have a wingspan of 10 to 12 inches (26 to 30 cm) (Harvey et al. 2011). The pelage is a gray brown to dark brown above and whitish with dark rooted hairs below, and the hair on the claws extend past the toes.

## Taxonomy

Two subspecies are recognized, with *C. r. rafinesquii* occupying the Ohio River valley and Appalachian mountains of North and South Carolina, and *C. r. macrotis* occupying coastal plain regions (Handley 1959). Both subspecies are found in South Carolina. However, even though two lineages exist, Piaggio et al. (2011) found that they do not correlate to subspecies within the geographical boundaries proposed by Handley (1959) (Bat Conservation International and Southeastern Bat Diversity Network 2013).

## Distribution

Rafinesque's big-eared bat occurs throughout the South, ranging north to southern Illinois, Indiana and Ohio, west to southern Missouri and eastern Texas, and east to West Virginia, North Carolina, and Florida (Jones 1977, Hall 1981). This distribution has been thought to include most southern states (Harvey and Saugey 2001), but this species has yet to be found in the Piedmont of South Carolina and North Carolina (Bunch et al. 1998*a*, J. M. Menzel et al. 2003, Fields 2007, Bennett et al. 2008). *C. r. rafinesquii* is distributed within the southern Appalachian mountains from West Virginia south into South Carolina and Georgia, and *C. r. macrotis* is distributed along the Coastal Plain of North Carolina and South Carolina, and south into Georgia and Florida (Bunch et al. 2015*b*).




**Population Status**
Over most of its range, Rafinesque's big-eared bat is an uncommon species with scattered populations. Even though it is widespread in the South, it's not considered abundant and in the past century population levels appear to have declined (BCI and SBDN 2013). Rafinesque's big-eared bat has a rounded rank of Vulnerable both Globally (G3G4), and Nationally (N3N4), and is Subnationally Imperiled (S2?) (NatureServe 2017). However, it is currently ranked as Subnationally Imperiled (S2) by the SCDNR Heritage Trust (see Table 2). It is classified as Least Concern (LC) on the IUCN Red List (Arroyo-Cabrales and Álvarez-Castañeda 2008*e*). This species is listed as State Endangered, and is a Highest Priority species in the South Carolina 2015 SWAP (SCDNR 2015). It is estimated that around 4,000 Rafinesque's big-eared bats hibernate in six major cave roosts in the Appalachian Mountains and central plateaus of Kentucky and North Carolina, and that smaller colonies composed of less than 50 individuals exist throughout the southeast (BCI and SBDN 2013).

**General Habitat**
The Rafinesque's big-eared bat is usually found in mature bottomland hardwood forests of Mississippi and Ohio River valleys and the southeastern US (Brown and Brown 1993, Mirowsky 1998, Tuttle and Kennedy 2005) in stands of mature cypress (*Taxodium* species) and tupelo-gum (*Nyssa* species) (Lance et al. 2001, Trousdale and Beckett 2005, Carver and Ashley 2008). Other habitats used include open, mature, pine flatwoods in Florida and South Carolina (Brown 1997, Menzel et al. 2001*c*), mature oak-hickory forests in Kentucky (Hurst and Lacki 1999), mixed juniper (*Juniperus* species) and loblolly pine (*Pinus taeda*) habitat in Texas (Schmidly et al. 1977), and in hardwood stands surrounded by contrasting ecosystem habitats (known as hammocks) in Florida (Jennings 1958).

**Roosts and Roosting Behavior**
Rafinesque's big-eared bats are primarily found in roosts in hollow trees (Trousdale and Beckett 2005, Trousdale 2011), beneath bridges (Ferrara and Leberg 2005, Trousdale et al. 2008, Loeb and Zarnoch 2011), in buildings (Clark 1990), or in sandstone caves and mines at the north end of their range (Barbour and Davis 1969, Harvey et al. 1991). Less often they can also be found in tree crevices (Lance 1999), beneath loose bark (Handley 1959), and among dead leaves (Harper 1927). With the exception of certain caves or buildings used year-round (Jones and Suttkus 1975, Clark 1990, Hurst and Lacki 1999, Finn 2000), roost sites may vary seasonally (Loeb and Zarnoch 2011, Roby et al. 2011). Because this species is not

considered migratory, summer foraging grounds are usually near winter roosts.

During summer, Rafinesque's big-eared bats are primarily found roosting in hollow trees, under bark, on bridges, and in abandoned buildings (Barbour and Davis 1969, Johnson and Lacki 2011, Loeb and Zarnoch 2011). Roost trees usually stand 59 to 82 feet (18 to 25 m) tall, have large cavities greater than 3.6 feet (102 cm) tall and 1.3 feet (39 cm) wide, and tend to be near water (Mirowsky 1998, Gooding and Langford 2004, Trousdale and Beckett 2005, Carver and Ashley 2008). In South Carolina, Rafinesque's big-eared bats have been found in human-made roost towers in the Blue Ridge and Piedmont regions (Greenville and Pickens Counties), the Sandhills region (Aiken and Richland Counties), and in the Coastal Plain (Hampton County). The Coastal Plains and Sandhill populations in the state (those of *C. r. macrotis*) roost in abandoned buildings, I- and T-beam bridges, old bunkers and tunnels, and large tree cavities (Menzel et al. 2001*c*, Bennett et al. 2008, Loeb and Zarnoch 2011, Bunch et al. 2015*b*). Habitats utilized by this subspecies include black gum (*Nyssa sylvatica*) and water tupelo (*Nyssa aquatic*) stands, bald cypress (*Taxodium distichum*) swamp forests, maritime forests, and hardwood or mixed mature forested bottomlands (Cochran 1999, Hofmann et al. 1999, Lance et al. 2001, Gooding and Langford 2004, Trousdale and Beckett 2005). Loeb and Zarnoch (2011) found that anthropogenic roosts were used significantly more than tree roosts during summer in the Coastal Plain of South Carolina, and that anthropogenic roost use was higher in summer than in all other seasons. Mountain populations (those of *C. r. rafinesquii*) in summer use roosts in cavity trees such as tulip poplars (*Liriodendron tulipifera*), abandoned buildings, cave or rock shelters, and abandoned mines (Bunch et al. 1998*a*, Clark et al. 1998, Bunch and Dye 1999*a*). Habitats utilized by this subspecies include rock outcrops for roosting, mesic and cove hardwood forests, dry deciduous forests, pine woodlands, forested wetlands and bottomlands, bottomland agricultural fields, and forested riparian areas (Trousdale and Beckett 2002, 2004, Johnson and Lacki 2013, Bunch et al. 2015*b*). Bennett (2006) found that though Rafinesque's big-eared bats occupied bridges in the Upper and Lower Coastal Plain, they were absent from bridges in the Piedmont and Blue Ridge Mountains.

In spring during inclement weather, adult females have been known to enter shallow torpor before parturition takes place, with solitary individuals being observed in torpor more often than those in clusters (Clark 1990). However, males and non-reproductive females are still known to enter more daily torpor bouts than reproductive females (Johnson et al. 2012).

Nursery colonies form in spring between early April and late May (Jones and Suttkus 1975, Clark 1990), typically on vertical surfaces inside trees (Carver and Ashley 2008, Stevenson 2008), caves, mines, or other karst features (Barbour and Davis 1969, Harvey et al. 1999*a*). The size of summer colonies can range from a couple to 50, and sometimes even up to 300 (BCI and SBDN 2013). Roost tree density affects the social structure of Rafinesque's big-eared bats, where lower densities may lead to the use of only one focal maternity roost (Johnson et al. 2012). Though some reproductive males have been found roosting with pregnant and lactating females, the majority of adult males roost alone during summer (Hurst 1997). In South Carolina, maternity colonies have been found in abandoned buildings in Aiken County (M. A. Menzel et al. 2003), a gold mine in Oconee County, bridges (Bennett et al. 2003*b*), and in tree cavities with approximately 100 individuals at Congaree National Park (National Park Service 2004).

In mid-August, female clusters are joined by other individuals after the nursing period (Hall 1963, Barbour and Davis 1969, England et al. 1990), though rarely do they include males (Clark 1990). From September through October, nursery colonies disperse (Jones and Suttkus 1975, Clark 1990). In the coastal plains, warmer buildings and trees are left behind in search of microclimates that have a cooler and more stable temperatures such as cooler trees (Clark 1990, Rice 2009), cisterns and abandoned water wells (Schmidly 1983). Rafinesque's big-eared bats are considered sedentary because they haven't been found any further than 2.1 miles (3.4 km) from primary roosting sites in bottomland forests (Finn 2000, Johnson and Lacki 2011) and 1.6 miles (2.6 km) (England and Saugey 1998, Hurst and Lacki 1999, Lance et al. 2001) from roosting sites in upland forests.

During winter in the northern portions of its range, this species hibernates for short periods of time and is known to move between roost sites (Hoffmeister and Goodpaster 1963, Jones and Suttkus 1975, Hurst and Lacki 1999). Generally, this species is found hibernating in mines, caves, cisterns, and wells (Barbour and Davis 1969, England and Saugey 1999, Harvey et al. 1999*a*) from November to March (England et al. 1990, Whitaker and Hamilton 1998). However, they have also been found roosting in buildings year round in North Carolina (Clark 1990). In the South, Rafinesque's big-eared bats enter torpor when the weather turns cold (Jones and Suttkus 1975), but are otherwise thought to be active year round (Ferrara and Leberg 2005). In the Coastal Plain where caves, mines, or other karst features are unavailable, this species may remain in large hollow trees of closed canopy bottomland hardwood forests. Rafinesque's big-eared bats also adjust roosting height seasonally in trunk hollows, moving from the bottom of the tree cavity to the top during winter (Rice 2009). Alternatively, this species may choose larger diameter trees in winter than in spring and summer, as they've been known to do in the bottomland hardwood forests of Mississippi (Fleming et al. 2013). In South Carolina, Rafinesque's big-eared bats have been found using a gold mine in Oconee County and abandoned buildings in Aiken County as hibernacula. They've been known to use a different location within these same sites for a maternity roost or hibernacula, depending on the season.

There is evidence that this species switches roosts often but still has high site fidelity to groups of hollow trees (Gooding and Langford 2004, Trousdale and Beckett 2005, Johnson and Lacki 2011, Trousdale 2011), and roost sites beneath bridges (Ferrara and Leberg 2005, Trousdale et al. 2008, Loeb and Zarnoch 2011). Rafinesque's big-eared bats that roost beneath the same bridges are thought to also frequently use other roosts (Ferrara and Leberg 2005, Bennett et al. 2008). These movements, as well as clustering, seem to be correlated with air temperature (Hoffmeister and Goodpaster 1963, McNab 1974, Jones and Suttkus 1975). For undisturbed bats living in buildings, roost switching is relatively rare (Clark 1990).

**Reproduction**

Though there have been reports of individuals breeding in mid-February and mid-March (Goodpaster and Hoffmeister 1952, Clark 1990), mating is generally thought to occur in the fall and winter, and sperm is stored in the female's uterus until spring when fertilization takes place (Hoffmeister and Goodpaster 1963, Barbour and Davis 1969). A single pup is usually born between mid-May in the deep-south, or late-May to early June in the northern portion of their range (Jones 1977, Harvey et al. 1999*a*). The gestation period from one report of a captive female was 93 days (Clark 1990). Females may carry young from one roost to another, adding an additional 66% of their own body weight (Jones and Suttkus 1971, England et al. 1990). Young begin to fly after three weeks (Jones 1977). It is not until their second year that males become sexually mature (Jones and Suttkus 1975, England et al. 1990).

**Food Habits and Foraging**

This species may emerge late in the evening to forage (Harvey et al. 1999*a*), though in South Carolina they have been found to emerge not long after sunset until around midnight before emerging again to forage a few hours before sunrise (Menzel et al. 2001*c*).

The Rafinesque's big-eared bat is a highly maneuverable flier that can navigate well in dense vegetation and hover in place (Belwood 1992), often foraging about 3 feet (1 m) from the ground gleaning insects from foliage (Barbour and Davis 1969, Clark 1991, Ellis 1993). In North Carolina, this species avoided large open areas such as fields, roadways, and open water (Clark 1990, 1991). Large nursery colonies have been reported to forage along mid-slope ridges in mature oak-hickory forests of Kentucky (Hurst and Lacki 1999). In South Carolina, swamp forests represented the majority of the area used by radio-tagged bats in the forested old growth swamp at Francis Beidler Forest (Clark et al. 1998). At the Silver Bluff Plantation in the Upper Coastal Plain, reproductive males fed in uplands in young pine stands where sapling stage stands were preferred over sawtimber stands, despite the fact that mature bottomland hardwoods were common in the study area (Menzel et al. 2001*c*). Rafinesque's big-eared bats in the mountains of South Carolina that had been captured and fitted with radio transmitters in the Eastatoe Valley foraged in and around forested bottomlands and a cornfield in Eastatoe Valley (Mary Bunch, SCDNR, pers. comm.). In Kentucky, this species was found closer to upland deciduous forest and forested and herbaceous wetlands than agricultural areas and open fields (Johnson and Lacki 2011). Also during this study, pregnant females traveled from forested wetland roost sites to foraging sites in deciduous forests on dry soil with rich Lepidoptera abundance. In Florida, wetland and pastures were preferred over palmetto and non-forested wetlands (Finn 2000), though foraging areas varied seasonally as forested wetlands were used from November to February and upland oak forests from August to April. In South Carolina, this species has been found foraging less than 0.62 miles (1 km) from roosting sites in an average home range area of 230 acres (93 ha) in the Upper Coastal Plain (Menzel et al. 2001*c*). This differs from the Francis Beidler Forest study in the Outer Coastal Plain, which found a smaller average home range of 190 acres (77 ha). Studies in Kentucky show similar distances from roosting sites to foraging areas as Menzel et al. (2001), but foraging areas averaged even larger at 352 acres (143 ha) (Hurst and Lacki 1999). The activity of Rafinesque's big-eared bats has been recorded in July in South Carolina in July at the Bad Creek Hydroelectric Project, Eastatoe Creek, and shoreline on Lake Jocassee on the west side of Double Spring Mountain (Webster 2013).

Lepidoptera is the primary food source of Rafinesque's big-eared bats in South Carolina and elsewhere (Donahue 1998, Menzel et al. 2002*a*, Armbruster 2003, Lacki et al. 2007), with moths comprising the vast majority of prey consumed in Kentucky (Hurst and Lacki 1997). Hurst and Lacki also reported Coleoptera, Homoptera, Diptera, Hemiptera, Hymenoptera, and Trichoptera as other insects consumed, in decreasing volume. A variety of moth species are consumed by Rafinesque's big-eared bat, seen by the 22 species from six families reported by Lacki and LaDeur (2001). In North Carolina, almost one third of the diet of this species consisted of horse and deer flies (Ellis 1993).

**Seasonal Movements**

Rafinesque's big-eared bats are considered sedentary, as their summer foraging grounds are usually near winter roosts and they haven't been found any further than 2.1 miles (3.4 km) (Finn 2000, Johnson and Lacki 2011) from primary roosting sites.

**Longevity and Survival**

The longest lived Rafinesque's big-eared bat was a banded individual in West Virginia reported at 10 years old (Paradiso and Greenhall 1967). Juvenile mortality for this species varies across studies, but in South Carolina the rate has been reported as high as 40 to 60% (Armbruster 2003).

**Threats**

Since 1975, populations of Rafinesque's big-eared bat have been declining in some areas (Jones and Suttkus 1975). Mortality on this species is not well documented, but the loss of roosting habitat, vandalism by humans, predation, and flooding are reported most frequently (Clark 1990, Finn 2000, Bennett et al. 2004). Disturbance at roost and maternity sites in caves, buildings, and rock shelters also threatens Rafinesque's big-eared bats (Clark 1990, Lacki 2000).

Loss and degradation of bottomland hardwood forest habitat through clearing and drainage, coupled with the disappearance of extra large tree hollows, has likely been the major threat and long-time driving factor contributing to limited populations and vulnerability of Rafinesque's big-eared bats (Tiner 1984, Clark 2000, Mitsch and Gosselink 2001). Loss of forest woody plant diversity necessary for the development of the main prey species of these bats may threaten their survival as well (Dodd et al. 2008, 2012, Lacki and Dodd 2011). Destruction and fragmentation of mature forests in the mountains and Coastal Plain is another potential threat (Bunch et al. 2015*b*). Additionally, the loss of human-made structures that more recently took the place of tree hollows as colonial roosts may be a problem in some areas (Clark 1990, Belwood 1992, Lance 1999).

Rafinesque's big-eared bat may be particularly vulnerable to pesticides given its reliance on moths (Hurst and Lacki 1999, Lacki and LaDeur 2001). Pesticides have been shown to cause population declines in insectivorous bats (Geluso et al. 1976, Reidinger 1976, Brady et al. 1982), and can alter behavior, cause mortality, and be transferred to nursing young (Clark 1981, 1986, Henny et al. 1982).
Potentially, deforestation from gypsy moths (*Lymantria dispar*) and/or control measures for gypsy moths, such as broadcast usage of *Bacillus thurinigiensis* var. *kurstaki* may impact this bat species, as well as heavy metals (Bunch et al. 2015*b*).

The genetic isolation of populations is another threat to Rafinesque's big-eared bats (Bunch et al. 2015*b*). Due to the fact that populations are becoming smaller and more isolated, this species has also become more vulnerable to natural threats such as hurricanes (Clark 2000).

Other potential threats reported by Bunch et al. (2015*b*) include alteration of natural flood regimes that may affect the regeneration of important forest community types such as cypress-gum, thus preventing recruitment of future roost trees. These alterations may also flood natural roosts. Abundant invasive exotic vegetation, such as some privet species, may

prevent the regeneration of forest species and impair recruitment of suitable roost trees. Additionally, feral cats also pose a threat as unnatural predators at roosts.
The inadequacy of existing regulations for management of forestry, wind energy development, and oil, gas, and mineral extraction, especially when it comes to the protections afforded a state-listed species, may be another threat to Rafinesque's big-eared bat. These protections are meant to prevent trade or possession of state-listed species, but do not to protect against habitat destruction (USFWS 2011).

WNS could be a potential problem, as it has been detected on Rafinesque's big-eared bats. However, this species has not yet shown diagnostic sign of the disease (White-nose Syndrome.org 2015).

Deforestation of oak (*Quercus* species) from Sudden Oak Death (SOD) disease caused by the plant pathogen *Phytophthora ramorum* may pose a threat to habitats critical to forest-dwelling bats. Though it has not been found in a natural setting to date, this disease was recently detected on nursery stock in South Carolina (Bunch et al. 2015*b*).

**Conservation Measures**
Bat exclusion, not extermination, is the most effective and humane way to remove bats from buildings. Sealing out bats and/or adding more light to the roost of a colony are more effective alternatives than use of pesticides for control purposes (Laidlaw and Fenton 1971, Barclay et al. 1980). To minimize negative impacts to Rafinesque's big-eared bats, eviction from buildings should include appropriately timed exclusion methods. To avoid the maternity period, bats should not be evicted from May through July. Alternatively, populations at the roost area may be decreased by 41 to 96% if lights are introduced to the area (Laidlaw and Fenton 1971). Measures should be taken to provide species-specific alternate roost structures before eviction, and structures that mimic large hollow trees such as large bat towers may be a suitable alternative for Rafinesque's big-eared bats.

Conservation measures include conserving old-growth forests and reestablishing corridors connecting suitable habitat (Clark 2000); protecting mature bottomland hardwood forests and recruitment of younger stages of high quality bottomland habitat for growth into future roost trees; and providing artificial roosts in areas of depleted roosting resources (Clark and Williams 1993).

Other habitat protection and management recommendations from Bunch et al. (2015*b*) include working to prevent or reduce disturbance to natural and artificial roost structures, as well as to maternity colonies and hibernacula through gating, warning or interpretive signs, prevention of trails or roads to these sites, and other protective measures; retain and recruit cypress-gum swamp forests with large cavity trees; designate no-cut buffer zones around known roosts; provide forested corridors between harvested units; and protect foraging areas and migration corridors, which could be done through landowner incentive programs, conservation easements, lease agreements, or purchases. Other measures may include providing, protecting, and maintaining large diameter roost trees, large snags, decadent trees, hollow trees, and roost structures, especially near water or riparian areas; attempting to create or maintain patches of structurally diverse forest in order to provide a wide variety of suitable roosting and maternity sites; minimizing large-scale pesticide use whenever possible; and protecting habitat above or around maternity roosts and known foraging areas from pesticides.

Priority survey and research recommendations from Bunch et al. (2015*b*) include continuing long-term monitoring of bridges in the Coastal Plain for Rafinesque's big-eared bats; continue long-term monitoring of Rafinesque's big-eared bat roosts in the mountains; determine if prescribed fire represents any threat, and also determine the acceptable distance of fire, smoke and fire lines from roosts; determine the genetic structure of selected colonies and test whether populations are experiencing adverse genetic consequences from isolation and fragmentation; survey and map mines, tunnels, wells and cave-like structures not surveyed in previous efforts; obtain long-term demographic data including reproductive success, sex ratios, survival, immigration and emigration facilitated by dispersal, and determine the effects of biotic and abiotic factors on these parameters; determine if unnatural predation at roosts by feral cats is occurring; determine alternate roost sites for bridge roosting individuals; locate and map roost trees by physical searches where possible; determine foraging habitat requirements (habitat types, size, and distance from roosts); use existing data on habitat preferences to identify the availability of natural roost habitat and to determine the amount of protected versus unprotected habitat; determine the effects of habitat fragmentation and roads on foraging behavior of Rafinesque's big-eared bats; study the feeding ecology requirements in the mountains and Coastal Plain; conduct seasonal surveys at caves and mines being considered for closure; and evaluate roost and appropriate food (insects high in polyunsaturated fats) availability, as well as roost temperatures, and compare these factors with winter survival. The SCDNR Heritage Trust tracks high priority species including Rafinesque's big-eared bat, and researchers are requested to submit bat data and occurrence records to their database.

Education and outreach goals recommended by Bunch et al. (2015*b*) include working to create general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans.

# Seminole Bat (*Lasiurus seminolus*)

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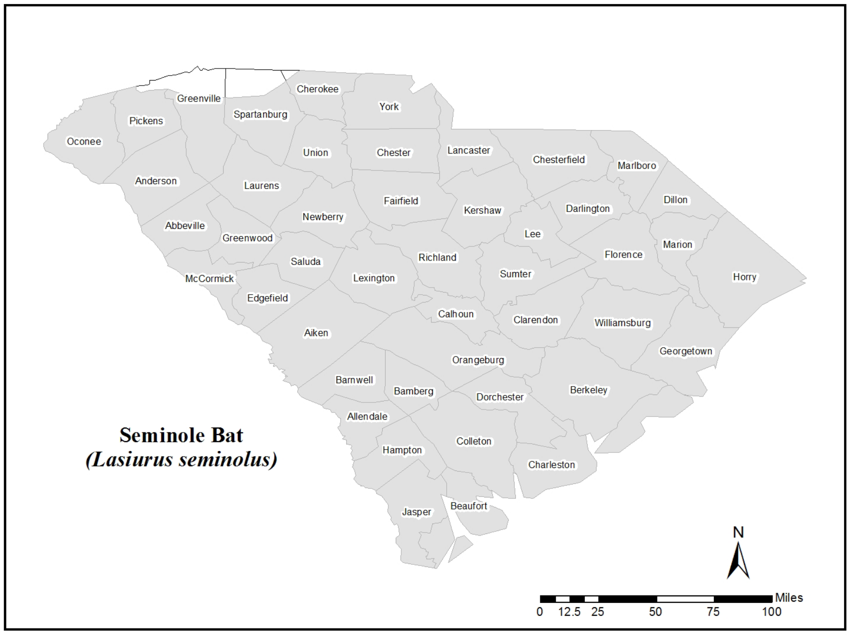
### Description
Throughout the southeast, the Seminole bat is one of the most common bats seen flying in the evening, especially on warm winter nights (Harvey et al. 2011). As with the northern yellow bat, this species roosts in Spanish moss (*Tillandsia usneoides*) and therefore is very closely associated with lowland wooded areas where Spanish moss occurs (Barbour and Davis 1969). The Seminole bat was once considered to be a subspecies of the eastern red bat (*Lasiurus borealis*) due to its similar size and appearance, but the color of the pelage distinguishes these species, as eastern red bats are more brick red in color.

### Identification
The Seminole bat is a medium sized bat with a rich mahogany pelage frosted with white tips above, and slightly paler below. This species weighs 0.3 to 0.5 ounces (9 to 14 gr) and has a wingspan of 11 to 12 inches (29 to 31 cm) (Harvey et al. 2011). Their furred ears are short and rounded, and the tail membrane is furred to the tip of its tail. The wings of this species are long and pointed. They are similar to eastern red bats in that they have distinctive white patches on the wrist and shoulder.

### Taxonomy
The Seminole bat is considered monotypic (Wilson and Reeder 2005).

### Distribution
Seminole bats typically range from the southeastern tip of Virginia south to Florida, west to east Texas along the Gulf Coast States, and north to southeastern Oklahoma and southern Arkansas (Wilkins 1987). There are a few isolated records as far north as New York and Pennsylvania (Poole 1949, Layne 1955). In South Carolina, this species is commonly found in the upper and lower Coastal Plain, but there are also a few fall and summer records in the Piedmont and Blue Ridge regions (M. A. Menzel et al. 2003).

### Population Status
Considered common throughout the Deep South, the Seminole bat is ranked as Globally Secure (G5), Nationally Secure (N5) and Subnationally Unranked (SNR) (NatureServe 2017). However, it is currently ranked as Subnationally Apparently Secure (S4?) by the SCDNR Heritage Trust (see Table 2). It is classified as Least Concern (LC) on the IUCN Red List (Timm and Arroyo-Cabrales 2008). There are no population density estimates for this species, though in suitable habitat it is thought to be abundant (Barbour and Davis 1969, Lowery 1974, Webster et al. 1985, Schmidly 1991). The Seminole bat is listed as a Highest Priority species in the South Carolina 2015 SWAP (SCDNR 2015), due in part to severe WNS-related mortality occurring in other bat species




**General Habitat**

Seminole bats are found in lowland wooded areas where Spanish moss occurs, often in mature pine-dominated forest such as pine-oak (*Pinus-Quercus*) and longleaf pine (*P. palustris*), mixed pine-hardwood, upland hardwood forests, islands, prairies, shrub swamp, blackgum (*Nyssa sylvatica*) forest, pure bay forest, bald cypress (*Taxodium distichum*) and pure and mixed cypress (Laerm et al. 1980, Menzel et al. 1998, 1999*a*, 2000*a*, Perry and Thill 2007*a*, Hein et al. 2008*b*).

**Roosts and Roosting Behavior**

Seminole bats roost solitarily, commonly in oak hammock communities in Spanish moss from fall through spring and even during winter (Constantine 1958, Jennings 1958, Barbour and Davis 1969), but also in the canopy of live pine trees (Menzel et al. 1998, 1999*a*, 2000*a*, Perry and Thill 2007*a*). This species may also opportunistically roost in mines or caverns (Heath et al. 1983). Roost sites are often selected with west and southwest exposures that are thought to provide warmth from the sun (Constantine 1958, Wilkins 1987). Seminole bats may roost at heights great enough to drop into unobstructed space in order to take flight, which vary from 3.6 to 14.8 feet (1.1 to 4.5 m), but may roost closer to the forest floor during colder weather (Constantine 1958).

During summer, this species primarily roosts in Spanish moss (Barbour and Davis 1969), and sometimes under loose bark (Sealander 1979). In South Carolina, they also roost in the terminal branches of pine limbs in pine dominated communities (Menzel et al. 1998), and at the Savannah River Site roosts were primarily located in loblolly pines (*Pinus taeda*) (Menzel et al. 2000*a*). In the latter study, roosts tended to be in taller, larger trees found in areas with higher basal area, lower species richness understory, and less Spanish moss than neighboring trees. Also in this study, Seminole bats showed low roost site fidelity as they stayed at each roost tree for an average of 1.7 days, but relatively high site fidelity as they switched to new roost trees within 0.62 acres (0.25 ha) area of their home range. This suggests that stand and landscape features may be influence roost-site selection more than tree and plot characteristics (Lunney et al. 1988, Cryan et al. 2001, Elmore et al. 2004).

In the lower Coastal Plain of South Carolina, Seminole bats roosted exclusively in the canopy of live loblolly pines and proximity to habitat edge was negatively related to both male and females (Hein 2008). Other studies show that Seminole bats may often switch roosts but go back to trees or roost sites previously used (Perry and Thill 2007*a*, Hein et al. 2008*b*). According to another study in South Carolina by Hein et al. (2008*b*), 63% of males and 61% of female roosts were found in forested corridors, with differences in habitat selection between the sexes and reproductive condition. Males chose sites nearest corridors and open stands, and roosts were evenly distributed among mid-rotation, mature pine, and mixed pine-hardwood stands. Nonreproductive females selected sites nearest corridors and forest edges, but did not select for a particular stand type. Reproductive females chose sites nearest forested edge and mature pine stands, with roosts found primarily in mature pine habitat, and larger and taller trees selected for than males or nonreproductive females. Increased solar exposure from these roosts may play a factor in roost selection as they are beneficial to the growth of prenatal and juvenile bats (Racey and Swift 1981, Vonhof and Barclay 1996, Willis and Brigham 2005).

During winter, Seminole bats may have a basal metabolic rate that resembles hibernation (Genoud 1990). However, they do not enter a deep torpor lasting the entire season but arouse and forage on warm nights, especially in the southern parts of their range (Wilkins 1987). In Florida, they don't generally fly when temperatures are less than 64°F (18°C) (Jennings 1958). This species commonly utilizes oak hammock communities in Spanish moss during winter (Constantine 1958). In South Carolina, males have also been known to roost in overstory trees and clusters of pine needles, understory vegetation, and found in leaf litter on the forest floor for up to 12 consecutive days during colder winter weather (Hein et al. 2005, 2008*b*). Male Seminole bats were reported as selecting taller trees in mature forest stands on warmer winter nights, but when minimum nightly temperatures were less than 39°F (4°C), they typically roosted in mid-rotation stands on or near the forest floor (Hein 2008).

**Reproduction**

Mating usually occurs in the fall, and probably in winter and spring (Constantine 1958), and sperm is stored in the female's uterus until spring when fertilization takes place. Twins are usually born between late May and June (Davis 1974). Pregnant females have been collected in May in South Carolina, Alabama, and Florida (Barkalow 1948, Moore 1949, Coleman 1950, Jennings 1958), and a lactating female was found as far north as New Hanover County in North Carolina (Barkalow and Funderburg 1960). Gestation lasts between 80 to 90 days, young are weaned and begin to fly at three to four weeks, and are probably sexually mature at the end of their first year (Barbour and Davis 1969, Wilson and Ruff 1999). Young bats also have a tendency to wander extensively after being weaned (Barbour and Davis 1969). The reproductive habits of the Seminole bat in South Carolina are unknown.

**Food Habits and Foraging**

Seminole bats are fast, direct flyers that forage at dusk. They feed at treetop level around 20 to 50 feet (6 to 15 m), 65 to 164 feet (20 to 30 m) above open water and along edges of cypress swamp, or glean prey from leaf surfaces or even the ground (Sherman 1935, Barbour and Davis 1969, Zinn 1977). They are also known to forage over forest clearings, woods, pine barrens, upland and bottomland hardwoods habitat and corridors, and sometimes coastal prairies and hammocks (Harper 1927, Menzel et al. 2002*b*, 2005*a*, *b*, Carter et al. 2004). However, their activity did not differ above, within, or below the forest canopy in a South Carolina study by Menzel et al. (2005) despite being considered a clutter-adapted species.

At the Savannah River Site in South Carolina, habitat types selected included 55% pine forests, 35% bottomland hardwoods, and 11% upland hardwoods (Carter et al. 2004). Foraging areas may not encompass roosting areas (Krishon et al. 1997), and may be relatively large. The home range size of five Seminole bats at the Savannah River Site averaged 1,045 acres (423 ha), ranging from 467 to 1,739 acres (189 ha to 704 ha) (Carter 1998). Hein et al. (2008*b*) reported that bats typically roosted in the same stand for the duration of the transmitter and that the mean roosting home range was 1.1 acres (0.46 ha) for males, 14.5 acres (5.85 ha) for reproductive females, and 0.5 acres (0.22 ha) for nonreproductive females.

Prey for this species include insects primarily from Coleoptera, Odonata, and Hymenoptera, but also Homoptera, Diptera, and Lepidoptera (Sherman 1935, Zinn 1977, Carter 1998, Donahue 1998, Carter et al. 2004). Seminole bats also opportunistically consume insects attracted to street lights (Jennings 1958).

**Seasonal Movements**

Seminole bats are thought to be mostly resident within their range, and are active during winter when the weather is warm enough (Jennings 1958). They have been reported year round in Texas, South Carolina, and Florida (Moore 1949, Coleman 1950, Schmidly et al. 1977). Seasonal migration is also thought to occur within their range, as the abundance of this species increases in the southern portion and decreases in the northern portion (Kunz and Racey 1998, Wilhide et al. 1998). However, no evidence has conclusively demonstrated that Seminole bats have migratory behavior (Wilkins 1987) and unusual occurrences of individuals outside the known range may have to do with the tendency for young to wander (Barbour and Davis 1969).

**Longevity and Survival**

The longevity and survival of Seminole bats is unknown. A higher mortality rate of males has been observed, as fewer males have been recorded in the older age class than females. As with many bats, juvenile Seminole bats most likely have a higher mortality than adults (Kunz and Racey 1998).

**Threats**

Wind energy may pose a small threat to Seminole bats, as fatality of this species at a wind power development at Buffalo Mountain Windfarm, Tennessee has been documented (Fiedler 2004, Johnson 2005). However, the fatalities reported are extremely low compared to those in migratory tree bats at wind-energy facilities. No wind turbines have been placed in South Carolina to date, however, Clemson University is constructing a test facility for turbines at the coast (Bunch et al. 2015*b*). Additionally, deadly collisions with towers in Florida have been recorded for this species (Crawford and Baker 1981). However, the level of impact from tower mortalities on local or range wide populations remains unclear.

Habitat and roost site loss due to development and removal of palm fronds are other potential threats for this species. The loss of Spanish moss due to a fungal infection such as the outbreak seen during the 1960's where Spanish moss was eliminated from many areas of central Florida (Smith and Wood 1975, Jensen 1982) is a potential threat. The harvesting of Spanish moss may still be of concern in some areas, but the development of synthetic materials replacing the need for Spanish moss has generally reduced this threat (Trani et al. 2007). Also, natural causes such as hurricanes may also create loss of habitat as well as direct mortality (Bunch et al. 2015*c*).

Pesticide poisoning, especially by organochlorines and anticholinestrase, is a threat to this species because it has been shown to cause population declines in insectivorous bats (Geluso et al. 1976, Reidinger 1976, Brady et al. 1982). Pesticides can also alter behavior, cause mortality, and be transferred to nursing young (Clark 1981, 1986, Henny et al. 1982).

**Conservation Measures**

Wind turbines are a relatively new threat, and thus very little research has been conducted on how to minimize the dangers of turbines to bats. What is known is that the new larger, taller turbines have decreased mortality in birds but actually increased bat fatalities (Barclay et al. 2007), and that facilities built on ridge tops appear to have the highest bat fatalities (Johnson and Erickson 2008). Research is greatly needed to identify the best placement of turbines, as well as strategies that would minimize impacts to bats (Ellison 2012). Wind turbine management recommendations from Bunch et al. (2015*c*) include working with wind energy development companies to mitigate the impacts of wind turbines, such as increasing the cut-in speed of turbines to reduce mortalities; and establishing timing and location of potential wind-energy conflicts through pre-construction surveys and determine potential mitigation measures to reduce mortality to Seminole bats. Also, using flashing lights instead of constant lights on towers, which is now regarded as acceptable by the FAA, can reduce bat mortality (Bunch et al. 2015*a*).

Other habitat protection and management recommendations from Bunch et al. (2015*c*) include working to retain upland forest corridors to prevent isolation of Seminole bats; minimize bat mortality during prescribed burn activities by burning in the spring or summer; advise forestry professionals to conduct controlled burns when minimum night temperatures are > 39°F (4°C) and temperatures at the time of ignition are > 50°F (10°C); maintain hedgerow habitats along crop borders; retain large trees in urban areas, and Spanish moss and old palm fronds on public lands; and timber management in the Piedmont region that includes pine thinning or controlled burns may benefit this species by creating more open forest areas. Other measures may include working to minimize or carefully consider large-scale pesticide use whenever possible, and protect habitat above or around maternity roosts and known foraging areas from pesticides. Additionally, management that provides suitable roosts include long rotations, complex canopy structure, and allowing snags to form (Menzel et al. 2000*a*), keeping in mind that pine plantations do not provide suitable roosting habitat due to lack of appropriate substrate such as foliage and tree cavities (Kern and Humphrey 1995).

Priority survey and research recommendations from Bunch et al. (2015*c*) include conducting further research to better understand general habitat requirements, population status, summer and winter roost sites, winter habitat, migration information, and behavior of Seminole bats; determine the extent and seasonality of off-shore commuting and foraging to assess vulnerability of Seminole bats to off-shore wind development; and determine the vulnerability of Seminole bats, especially during fall migration, to coastal wind energy development. Researchers are requested to collect and record bat data, but the SCDNR Heritage Trust does not track this species in its database.

Education and outreach goals recommended by Bunch et al. (2015*c*) include creating general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans; and discourage the practice of removing roosting habitat such as old palm fronds and large amounts of Spanish moss from trees.

# Silver-haired Bat (*Lasionycteris noctivagas)*

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## Description

One of the most common bats found in forested habitats across most of the US, the silver-haired bat is easily recognized by its blackish-brown pelage with silvery-white tips above, and paler with less pronounced frosting below. This solitary tree roosting bat is highly dependent upon old-growth forests, and one of the slowest flying bats in North America with a flight speed of 10.7 to 11.2 miles per hour (17.28 to 18 kmph) (Naumann 1999). Silver-haired bats migrate from northern areas during fall to more southern locations to hibernate in caves at 28.4 to 31.1°F (-.05 to -2°C), and/or use daily torpor interspersed with bouts of foraging in warmer areas (Humphrey 1975, Nagorsen and Brigham 1993, Dunbar 2007, Falxa 2007). These seasonal migrations can be quite extensive. For example, McGuire et al. (2012) predicted that this species could travel approximately 932 miles (1500 km) from the north side of Lake Erie to the southeastern US in five to six nights without refueling.

## Identification

This medium sized bat has black ears that are hairless, rounded and short with a blunt tragus. The wing and tail membranes are black, and the basal upper half of the outside of the tail membrane is densely furred. The frosted appearance of the pelage in this bat is less pronounced in older bats. This species weighs 0.3 to 0.4 ounces (8 to 11 gr) and has a wingspan of 11 to 12 inches (27 to 31 cm) (Harvey et al. 2011).

## Taxonomy

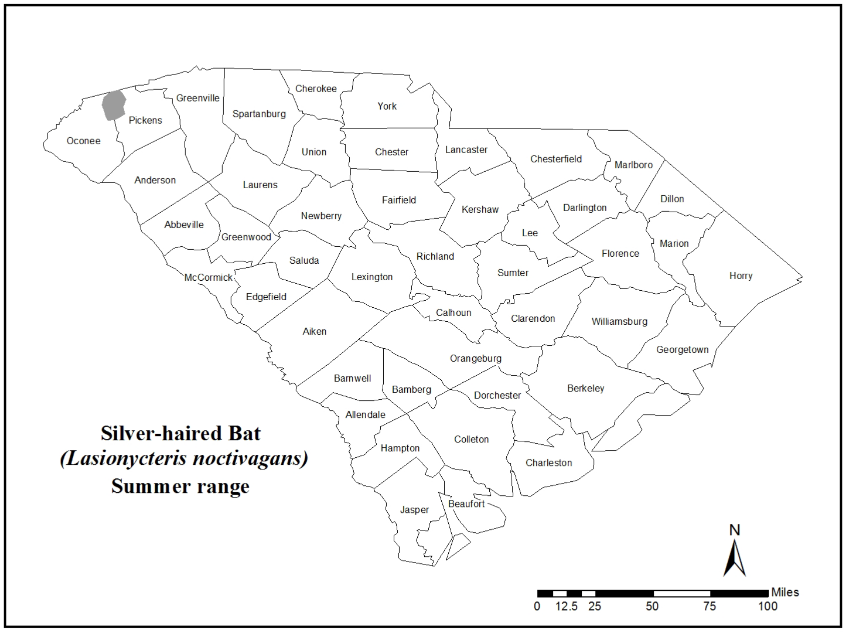
The silver-haired bat is considered a monotypic species (Wilson and Reeder 2005).

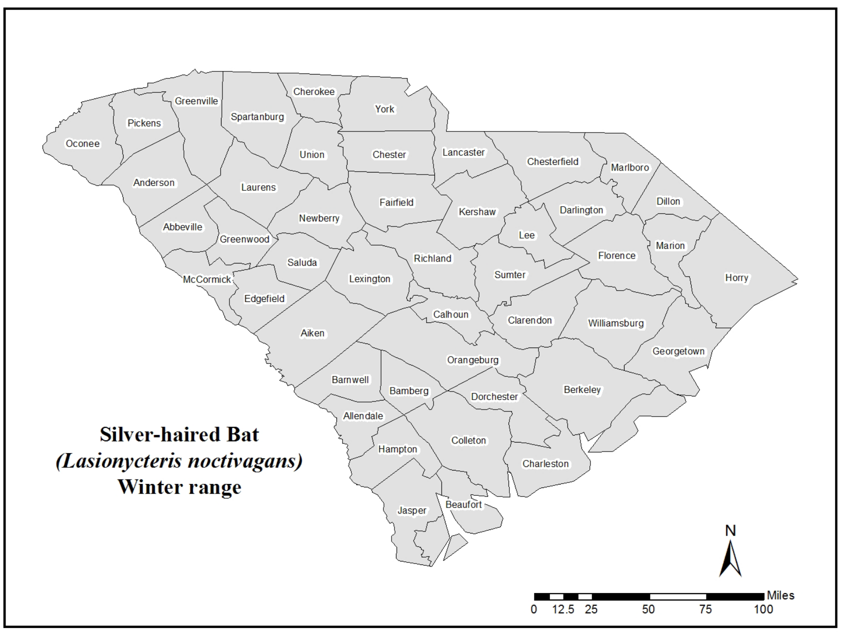
## Distribution

The silver-haired bat is distributed throughout southern Canada and most of the US, reaching its southern limit in the Southeast and Southwest (Kunz 1982*a*). In South Carolina, this species is distributed statewide and found in all four physiographic provinces (M. A. Menzel et al. 2003). However, this distribution may vary seasonally since individuals are known to migrate. During the winter they are distributed statewide, but during summer they are not generally found in the lower Piedmont or Coastal Plain (M. A. Menzel et al. 2003, Bunch et al. 2015*a*).

## Population Status

Considered widespread in the US, though perhaps erratic in abundance (Barbour and Davis 1969), the silver-haired bat has a rounded rank of Globally Vulnerable (G3G4), Nationally Secure (N5) and is Subnationally Unranked (SNR) (NatureServe 2017). It is currently classified as Least Concern (LC) on the IUCN Red List (Arroyo-Cabrales et al. 2008*b*). However, this species is listed as a Highest




Priority species in the South Carolina 2015 SWAP (SCDNR 2015), due to severe WNS-related mortality occurring in other bat species, and the fact that *P.d.* has been detected on silver-haired bats but no diagnostic sign of WNS has been documented.

**General Habitat**

This species is typically found in forests and riparian zones including those in deciduous, coniferous, and mixed coniferous types adjacent to water (Kunz 1982*a*, Whitaker and Hamilton 1998, Nowak 1999). Old-growth habitats with more diverse structure tend to be preferred for both roost availability and foraging suitability (Thomas 1988, Jung et al. 1999). In Washington, silver-haired bats also occur in suburban and developed areas (Johnson and Cassidy 1997), and in Oregon are generally only found in shrub-steppe habitat during migration (Whitaker et al. 1981, Perkins and Cross 1988). The elevation range at which this species is found is between sea level to at least 6,000 feet (1,830 m) (Nagorsen and Brigham 1993, Christophersen and Kuntz 2003, Petterson 2009).

**Roosts and Roosting Behavior**

Silver-haired bats have been found roosting in trees (Cowan 1933, Jackson 1961), buildings (Frum 1953, Clark and Williams 1993), rock crevices (Frum 1953), and caves and mines (Beer 1956, Layne 1958, Pearson 1962, Baker 1965, Turner 1974). They have shown a roosting preference for forests with large numbers of snags (Campbell et al. 1996, Mattson et al. 1996, Betts 1998) and old-growth forests (Thomas 1988, Jung et al. 1999). There have been no studies investigating the roosting habits of silver-haired bats in South Carolina.

During summer, roosts and nursery sites are often found in tree foliage, under loose bark, in narrow crevices in tree trunks, or in old woodpecker cavities (Parsons et al. 1986, Betts 1996, Mattson et al. 1996, Vonhof and Barclay 1996). In Washington, roosts included dead or dying trees with exfoliating bark, extensive vertical cracks, or cavities, and were significantly taller than surrounding trees with less overstory, less understory, and shorter understory vegetation than comparable random plots (Campbell et al. 1996). In the same study, the height of summer roosts ranged between 20 to 50 feet (6.1 to 15.2 m). In southern British Columbia, silver-haired bats spent significantly more residence time in cavity roosts (14 days) than bark roosts (6 days), potentially due to cavity roosts containing maternity colonies (Vonhof and Barclay 1996). Where relatively large numbers of this species are found, populations are dominated by females during summer except in the montane west (Kunz 1982*a*).

Maternity colonies are relatively small on average, normally ranging from five to 25 females but sometimes up to 70 individuals (Rainey and Pierson 1994, Mattson et al. 1996, Vonhof and Barclay 1996). Maternity roosts are usually found in old woodpecker cavities (Parsons et al. 1986, Mattson et al. 1996, Vonhof and Barclay 1996) and in taller trees with retained tops protruding above the canopy (Betts 1998), possibly in order to better absorb sunlight and retain heat. In the study by Betts (1998), roost fidelity varied from the use of one to two roosts for eight to 13 days, or five to six roosts for one to six days, and colonies tended to stay together when switching between roosts.

Males and non-reproductive females generally roost alone (Humphrey 1975, Barclay et al. 1988, Betts 1998), and may switch roosts as often as every day (Campbell et al. 1996, Mattson et al. 1996). Day roosts of these individuals have been found in cavities as well as under loose bark on large trees in intermediate stages of decay (Mattson et al. 1996).

During late summer and early fall, migrating bats have been known to roost in narrow crevices in tree trunks (Barclay et al. 1988), and in trees and human-made structures such as buildings, lumber piles, utility poles, fence posts, and mines (Barbour and Davis 1969, Nagorsen and Brigham 1993, McGuire et al. 2012). Barclay et al. (1988) reported the height of roosts for migrating silver-haired to be between 2.9 to 11.5 feet (0.87 to 3.5 m) in Manitoba. In the same study, bats were located in trees with significantly larger circumferences than random samples. In Manitoba, 18 individuals of this species were found to be torpid for several days at temperatures below 68°F (20°C) during migration (Barclay et al. 1988).

During winter, large populations of this species migrate south to areas above a 20°F (-6.7°C) mean daily minimum temperature isotherm for January (Izor 1979). However, individuals may also hibernate in stable microclimates during winter to maintain energy, such as in caves at 28.4 to 31.1°F (-.05 to -2°C), and/or use daily torpor interspersed with bouts of foraging (Humphrey 1975, Nagorsen and Brigham 1993, Dunbar 2007, Falxa 2007). This species roosts alone or in small groups in hollow trees, under loose bark, at ground level, in houses, and sometimes in caves, abandoned mines, rock crevices, and rock outcrops (Kunz 1982*a*, Maser 1998, Perry et al. 2010). Perry et al. (2010) found that 90% of winter roosts were in five species of trees, and most were on southern topographic aspects. Of all roosts, 55% were under loose bark, 6% were either under a tree roost or in a cavity at the base of a live pine, and 3% were found in a rock outcrop, often on days colder than 41°F (5°C). Pine or pine-hardwood stands greater than 50 years old and used forest stands between 15 and 50 years old were selected as winter roosts by silver-haired bats in this study.

**Reproduction**
Mating probably occurs in the fall and winter, and sperm is stored in the female's uterus until spring when fertilization takes place between late April and early May (Druecker 1972, Kunz 1982*a*). Twins are usually born between June and July (Merriam 1884, Easterla and Watkins 1970, Kunz 1971). Gestation lasts 50 to 60 days, lactation lasts about 36 days and young begin to fly between three to five weeks (Kunz 1971, Druecker 1972, Nagorsen and Brigham 1993). Most males and females are thought to reach sexual maturity in their first year (Druecker 1972, Cryan et al. 2012).

**Food Habits and Foraging**
The silver-haired bat often emerges later in the evening after other species have left to forage (Seton 1907, Bailey 1929, Kunz 1973), and foraging activity has been shown to peak two to four hours after sunset and six to eight hours after sunset (Jones et al. 1973, Kunz 1973). This species has short, broad wings and a slow, agile flight of 10.4 to 11.2 miles per hour (4.8 to 5 mps) (Hayward and Davis 1964, Whitaker et al. 1977, Naumann 1999), and captures small insects at close range (Barclay 1985, Nagorsen and Brigham 1993).

Foraging habitats include mixed deciduous forests, coniferous forests, and riparian habitats next to or over bodies of water such as streams and ponds (Kunz 1982*a*). The silver-haired bat has been recorded as foraging in an area of about 151 to 299 feet (46 to 91 m) in diameter (Schwartz and Schwartz 1959). During migration, this species forages along intact riparian areas in arid rangelands of Oregon (Whitaker et al. 1981). In winter, foraging activity of silver-haired bats occurs during mild temperatures on rainless nights in Washington (Falxa 2007), and in Virginia and North Carolina they are active at 55°F (13°C) or more (Padgett and Rose 1991). In South Carolina, the activity of silver-haired bats has been recorded widely around Lake Jocassee and Lake Keowee in April, July and October at 27 of the 31 sites surveyed (Webster 2013).

Primary prey consumed by this species are generally moths (Black 1974), but also include other species from Lepidoptera as well as those from Hemiptera, Coleoptera, Diptera, Isoptera, and Trichoptera (Jones et al. 1973). Specimens from Indiana contained 90 to 100% Trichoptera and 10% Coleoptera, and those from Oregon contained 32% Lepidoptera, 15% Isoptera, and 26% Diptera (Whitaker 1972, Whitaker et al. 1977).

**Seasonal Movements**
Silver-haired bats are migratory over much of their range. This range is thought to shift to the north in the spring and to the south in the fall, though the southern shift appears to be more extensive in eastern than western North America (Baker 1978, Izor 1979). Females migrate further than males, and males are only present throughout the range during migration (Kunz 1982*a*). The timing of fall migration has been recorded to occur in two waves, primarily from August through September (Barclay 1984, Arnett et al. 2008, McGuire et al. 2012). In eastern North America, McGuire et al. (2012) predicted the fall migration rate of silver-haired bats from the north side of Lake Erie to the southeastern US be 155 to 170 miles (250 to 275 km) per night for five to six nights without refueling, even though brief

stopovers of one to two days do occur. However, migrating individuals do engage in feeding activity, especially on non-travel nights (Reimer et al. 2010, McGuire et al. 2012). Spring migration also happens in waves, and occurs along the southern shore of Lake Manitoba is in May and early June (Barclay et al. 1988).

**Longevity and Survival**
In a study by Schowalter et al. (1978), most individuals were estimated at two years old with the oldest being 12 years old.

**Threats**
Wind turbine facilities are the biggest major threat to this species as they are one of the species most commonly killed at wind farms in North America, composing about one-fifth of an estimated 450,000 bat fatalities at wind facilities annually (Cryan 2011, Ellison 2012). Because the silver-haired bat is one of three migratory tree bats that compose the majority of wind turbine fatalities, it has been suggested that seasonality and migration patterns make them more vulnerable to collisions (Cryan 2011). No wind turbines have been placed in South Carolina to date, however, Clemson University is constructing a test facility for turbines at the coast (Bunch et al. 2015*b*). Collisions with towers may also be a threat, as it has been with other foliage roosting bats in Florida (Crawford and Baker 1981).

Loss of roost habitat due to development and forestry practices may threaten populations of silver-haired bats. For example, the loss of existing snags and curtailed development of large snags from forestry practices means less maternity and roosting sites (Campbell et al. 1996, Mattson et al. 1996, Betts 1998). Loss of migration roosts and foraging habitat in riparian areas is another potential threat. Also, natural causes such as hurricanes may create loss of habitat as well as direct mortality (Bunch et al. 2015*c*).

Pesticide poisoning, especially by organochlorines and anticholinestrase, is a threat to this species because it has been shown to cause population declines in insectivorous bats (Geluso et al. 1976, Reidinger 1976, Brady et al. 1982). Pesticides can also alter behavior, cause mortality, and be transferred to nursing young (Clark 1981, 1986, Henny et al. 1982). This species may additionally be vulnerable to heavy metal contamination since they often forage over water.

WNS has the potential to be a threat to this species as it has been detected on silver-haired bats, but they have not yet shown diagnostic sign of the disease (White-nose Syndrome.org 2015).

**Conservation Measures**
Wind turbines are a relatively new threat, and thus very little research has been conducted on how to minimize the dangers of turbines to bats. What is known is that the new larger, taller turbines have decreased mortality in birds but actually increased bat fatalities (Barclay et al. 2007), and that facilities built on ridge tops appear to have the highest bat fatalities (Johnson and Erickson 2008). Research is greatly needed to identify the best placement of turbines, as well as strategies that would minimize impacts to bats (Ellison 2012). Wind turbine management recommendations for foliage roosting bats from Bunch et al. (2015*c*) include working with wind energy development companies to mitigate the impacts of wind turbines, such as increasing the cut-in speed of turbines to reduce mortalities; and establishing timing and location of potential wind-energy conflicts through pre-construction surveys and determine potential mitigation measures to

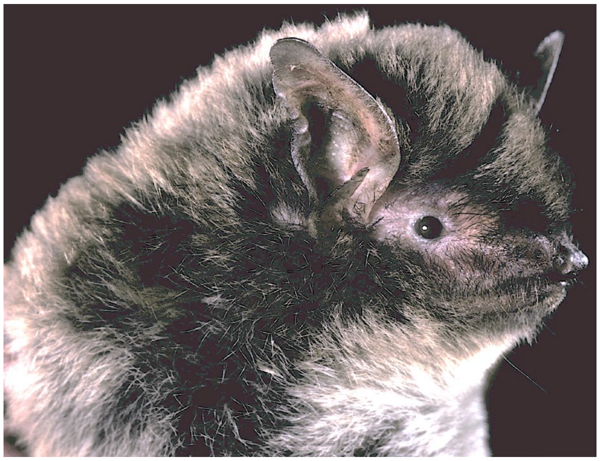
reduce mortality to silver-haired bats. Also, using flashing lights instead of constant lights on towers, which is now regarded as acceptable by the FAA, can reduce bat mortality (Bunch et al. 2015*a*).

Other habitat protection and management recommendations include working to recruit and retain small groups of suitable snags and maintain structural complexity in riparian areas and forest patches (Campbell et al. 1996); provide tall snags in the early stages of decay greater than 2 feet (60 cm) in diameter and exposed to solar radiation (Betts 1996, 1998, Campbell et al. 1996); retain snag density of greater than 21 snags per 2.5 acres (1 hectare) in timber harvest projects (Bunch et al. 2015*a*); and provide snags in open areas greater than 330 feet (100 m) upslope of riparian areas, since they are particularly useful to this species in dry inland forests (Campbell et al. 1996). Other measures may include working to minimize or carefully consider large-scale pesticide use whenever possible; and protect habitat above or around maternity roosts and known foraging areas from pesticides.

Priority survey and research recommendations from Bunch et al. (2015*a*) include determining migration routes, timing and patterns of the silver-haired bat; determining where South Carolina's over-wintering population migrates for the summer, perhaps by using stable isotopes from hair or nail samples; studying potential impacts from wind farms and develop strategies to reduce silver-haired bat mortality; determining winter roost site and habitat requirements; determining if silver-haired bats are threatened by pesticide and/or heavy metal contamination; and examining the impacts of winter burns during cold weather on silver-haired bats, particularly on south-facing burn units. The SCDNR Heritage Trust tracks high priority species including the silver-haired bat, and researchers are requested to submit bat data and occurrence records to their database.

Education and outreach goals recommended by Bunch et al. (2015*b*) include creating general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans.

# Southeastern Bat (*Myotis austroriparius*)



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## Description

The southeastern bat is endemic to bottomland hardwood forests of South Carolina's Coastal Plain, and are rarely far from cypress-gum swamps (Clement and Castleberry 2013*a*) and mature bottomland hardwood forests near lakes and slow moving streams (Cochran 1999, Hoffman 1999, Jones and Manning 1989). One of the unique characteristics of this species is that it's the only North American *Myotis* that normally gives birth to two young instead of one (Rice 1957). It has been hypothesized that because this species has longer periods of annual activity, having two young may be an adaptation to increased exposure to predation (Foster et al. 1978). Population estimates of the southeastern bat are extremely difficult to determine due to its scattered roosting habits and because data is lacking or scarce in many parts of its distribution (Whitaker and Hamilton 1998).

## Identification

The southeastern bat is a small to medium sized bat, with females generally larger than females. This species weighs 0.2 to 0.3 ounces (5 to 8 gr) and has a wingspan of 9 to 11 inches (24 to 27 cm) (Harvey et al. 2011). The calcar is unkeeled, the hairs between the toes extend to or past the claws, and the wing membrane attaches at the base of the toe. The tragus is relatively short and rounded compared to other *Myotis* species. The southeastern bat is highly variable in color, with tan or white below and three distinct dorsal pelage color phases including red, gray/brown, and a mixture of the two (Mirowsky 1998). Generally, the pelage is dark at the base with whitish tips, and is thick, wooly, and relatively short. This species resembles the little brown bat (*Myotis lucifugus*), but the little brown bat has conspicuously burnished hair tips, longer, silkier pelage, and does not have whitish tips on its underside.

## Taxonomy

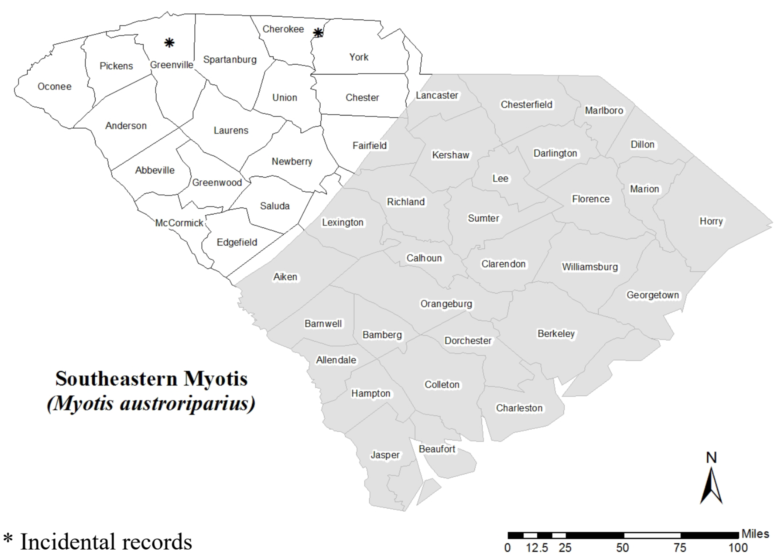
Though this species has been divided into three subspecies in the past, the southeastern bat is now considered monotypic (Wilson and Reeder 2005).

## Distribution

Southeastern bats are distributed through the southeastern US from southern Illinois and Indiana in the north, west to southeastern Oklahoma and northeastern Texas, south to northern Florida, and east to southern North Carolina (Hall 1981, Jones and Manning 1989). However, this species has yet to be found in the Piedmont of South Carolina and North Carolina, and is limited to upper and lower Coastal Plain of South Carolina (Fields 2007, Menzel et al. 2003).

## Population Status

Though the range of this species covers much of the southeastern US, range-wide population estimates are extremely difficult to determine due to the scattered roosting habits of this species and because data is lacking or scarce in many parts of its distribution (Whitaker and Hamilton 1998). However, it is



**Southeastern Myotis**
*(Myotis austroriparius)*

* Incidental records

these habitats include black gum (*Nyssa sylvatica*), water tupelo (*N. aquatica*), bald cypress (*Taxodium distichum*), water oak (*Quercus nigra*), willow oak (*Q. phellos*), and swamp chestnut oak (*Q. michauxii*) (Mirowsky and Horner 1997). Southeastern bats have also been found in upland pine forests (Reed 2004), oak-pine and longleaf pine (*P. palustris*) (Schmidly et al. 1977).

known that populations have decreased and this bat is no longer considered common. The southeastern bat has a rank of Globally Apparently Secure (G4), Nationally Apparently Secure (N4), and is Subnationally Critically Imperiled (S1) (NatureServe 2017). It is currently ranked as Subnationally Critically Imperiled (S1S2) by the SCDNR Heritage Trust (see Table 2). It is classified as Least Concern (LC) on the IUCN Red List (Arroyo-Cabrales and Álvarez-Castañeda 2008*f*). The southeastern bat is considered rare in South Carolina and is designated as threatened or "in need of management" (Bunch et al. 2015*b*). This species is a Highest Priority species in the South Carolina 2015 SWAP (SCDNR 2015)

**General Habitat**

Permanent sources of water play an important factor in the habitat associated with southeastern bats (Jones and Manning 1989). In the southern coastal plain and lowlands, this species is rarely far from cypress-gum swamps (Clement and Castleberry 2013*a*) and mature bottomland hardwood forests near lakes and slow moving streams (Cochran 1999, Hoffman 1999, Jones and Manning 1989). Common tree species associated with

**Roosts and Roosting Behavior**

Southeastern bats have generally been found roosting over water in caves, mines, hollow trees, bridges, buildings, wells, and cisterns (Rice 1957, Lowery 1974, Sealander 1979, Mumford and Whitaker 1982, BCI and SBDN 2013). In the northern and southeastern portion of its range, the preferred sites of this species are caves over water, such as Florida limestone caves where the largest summer colonies roost (Rice 1957, Harvey et al. 1991, Gore and Hovis 1998). Where caves are not available on the Gulf Coast, roosts used include hollow trees, buildings, and other protected sites (Lowery 1974, Foster et al. 1978, Sealander and Heidt 1990).

During summer, southeastern bats have been known to prefer larger trees with larger cavities within 66 feet (20 m) of standing water (Mirowsky 1998). The diameter at breast height (dbh) of roost trees are often large, varying from 30 to 61 inches (76 to 155 cm) (BCI and SBDN 2013). Southeastern bats have used various bottomland hardwood tree species such as large, live, hollow black gum and water tupelo with large basal openings (Cochran 1999, Hoffman 1999, Carver and

Ashley 2008), and sweetgum (*Liquidambar styraciflua*), Nuttall oak (*Q. nuttallii*), water hickory (*Carya aquatica*), water oak, red maple (*Acer rubrum*), and American sycamore (*Platanus occidentalis*) (Reed 2004, Wilf 2004, Stevenson 2008). In South Carolina, live tupelo gum trees within closed canopies were the primary roosting site in the Francis Beidler Forest (Clark et al. 1998). Despite being available, large bald cypress trees were not used as roost sites in Francis Beidler Forest or in areas in Texas, even though they are used as roost sites in Mississippi (Clark et al. 1998, Mirowsky 1998, Stevenson 2008). Roost tree entrances varied in height from 24 to 42 inches (60 to 106 cm) in Texas, Tennessee, and Illinois (Mirowsky 1998, Hofmann et al. 1999, Carver and Ashley 2008).

Maternity colonies are usually composed of around 100 to 300 individuals, though there have been reports of cave colonies that form around mid-March in Florida between 2,000 and 90,000 individuals (Rice 1957, Hoffman et al. 1998, Mirowsky 1998, Hoffman 1999). Maternity colonies are often found in live, mature hollow trees with large basal openings in species such as black gum, water tupelo, American sycamore, sweetgum, Nuttall oak, water hickory, American beech (*Fagus grandifolia*), bald cypress, Pignut hickory (*C. glabra*), swamp chestnut oak (*Q. michauxii*), and overcup oak (*Q. lyrata*) (BCI and SBDN 2013). Maternity colonies have also been found using bridges and culverts (Keeley and Tuttle 1999), cisterns (Sherman 2004), abandoned warehouses (Lee et al. 1982), and an attic in Florida that included up 7,680 southeastern bats and a few thousand Brazilian free-tailed bats (*Tadarida brasiliensis*) (Hermanson and Wilkins 1986). Bridges used include those with concrete arches, concrete flat slabs, and concrete I or T-beams, but do not include those made only of steel or wood (BCI and SBDN 2013), and channel beam bridges where preferred over other bridges in North Carolina (McDonnell 2001). An important factor contributing to roost selection of maternity colonies is consistent warm temperatures and high humidity (Rice 1957, Zinn 1977, Humphrey 1992), which may prevent evaporative water loss in lactating females (Webb et al. 1995). Along with reducing predation, this may explain why many colonies of southeastern bats roost over water (Foster et al. 1978). Nonbreeding females and males don't normally roost in maternity colonies, though males may join once the young are mature (Rice 1957).

Southeastern bats have a variable hibernation strategy, hibernating in the north during winter but staying active year-round in the southern portion of their range (Jones and Manning 1989). During winter in the northern portion of its range, this species is known to hibernate in caves and mines (Rice 1957, Barbour and Davis 1969). This bat may hibernate roosting alone or in groups that include males and females, and can be up to 120 individuals in Indiana, or 3,000 individuals in Kentucky (Barbour and Davis 1969, Hoffmeister 1989, Harvey et al. 1991). Abandoned mines are often used for hibernation roosts in areas where caves are not available, though they may also be used in the vicinity of caves (Smith and Parmalee 1954, Whitaker and Winter 1977). In Arkansas, this species hibernates in drill holes and crevices of abandoned cinnabar mine adits (Reed 2004), but roosts in warmer, more thermally stable mines in the southern end of the state instead of hibernating. Southeastern bats also roost in trees in winter, especially in southern regions. In Florida during winter, this species moves from caves that are too warm to facilitate torpor to exposed roosts in tree hollows, building, culverts, and bridges (Rice 1957, Humphrey 1992). One study found this species may prefer larger trees with larger cavities during winter than spring and summer (Fleming et al. 2013), but otherwise little information is available on winter roost tree characteristics. Southeastern bats are also documented wintering in cisterns (Sherman 2004), culverts (Walker et al. 1996), sheds (Barbour and Davis 1969), a fertilizer plant in Georgia (Davis and Rippy 1968), and in a warehouse in North Carolina that's used as a roost throughout the year (Lee et al. 1982). Overall, very few studies on winter or summer roosting habits of this species have been conducted in South Carolina, though a colony was discovered in a cave system in Orangeburg County which is used as both a summer and winter roost (J. M. Menzel et al. 2003).

**Reproduction**

Detailed reproductive and mating system information for the southeastern bat is poorly documented. However, mating is thought to occur in the fall in northern populations (Mumford and Whitaker 1982) and in spring in southern populations (Rice 1957, Amelon et al. 2006). Sperm is stored in the female's uterus until spring when fertilization takes place (Lowery 1974). Twins are usually born from April to mid-May (Rice 1957, Jones and Manning 1989), though probably from May to early June in South Carolina (M. A. Menzel et al. 2003). Gestation and lactation periods are unknown, but Rice (1957) reported that young begin to fly at five to six weeks. Also reported was the fact that young are carried by the female the first day after birth, but afterward they tend to form group clusters while the female is away foraging. Both males and females reach sexual maturity within their first year (Rice 1957, Whitaker and Hamilton 1998).

**Food Habits and Foraging**

Southeastern bats emerge to forage within the first three hours after sunset, and on warmer nights two peaks of foraging activity have been observed (Zinn and Humphrey 1981). This species prefers to forage over water in bald cypress-tupelo gum swamps and bottomland hardwood forests in Illinois, Arkansas, and South Carolina (Clark et al. 1998, Hoffman et al. 1998, Hoffman 1999). They are also found foraging over slow-moving creeks next to upland pine and hardwood forest and narrow beech-magnolia bottoms (Schmidly et al. 1977), in wetlands and mature forested wetlands (Gardner et al. 1992, Horner 1995, Gardner 2008), over water in managed pine forests (Miller 2003), and over livestock ponds (Bain 1981). In dry areas, they are found foraging in live oak habitats, fields, and upland woodlots (Zinn and Humphrey 1981, Humphrey 1992). In the Coastal Plain of South Carolina, southeastern bats are known to forage most actively in Carolina bay wetlands, bottomland hardwood forests and river swamps, and forest gaps, with most activity in stands of trees between 21 to 40 years (M. A. Menzel et al. 2003, Menzel et al. 2005*b*, Ford et al. 2006*a*).

The diet of southeastern bats can be variable (Whitaker and Hamilton 1998), and have been found to consume, in decreasing preference according to Zinn and Humphrey (1981), Diptera, Coleoptera, and Lepidoptera. Specifically, Zinn and Humphrey (1981) found this species selected for mosquitoes and crane flies on cool spring evenings, and Coleoptera, Lepidoptera, and culicid Diptera on warm summer nights when flying insects were diverse. Trichoptera composed a high percentage of this species diet in Illinois (Feldhamer et al. 2009).

The home range of this species is uncertain, but is thought to be between 250 to 1,240 acres (100 to 500 ha) (M. A. Menzel et al. 2003)

**Seasonal Movements**

Though winter hibernacula and summer maternity sites are generally located in different areas, this species is not considered a long-distance migrant because migration routes have not been documented (Rice 1957, Mumford and Whitaker 1982, Gardner et al. 1992). However, they could be considered a local migrant due to the small seasonal shifts that occur (Clement and Castleberry 2013*b*). For example, in Florida this species disperses from maternity colonies by the end of October and are completely gone by December (Rice 1957). Some banded individuals have been recorded as moving distances of 18 to 45 miles (29 to 72 km) (Rice 1957).

**Longevity and Survival**

The longest lived individual in the wild for this species has been recorded at 21 years, though the average lifespan may be closer to four to eight years (Nowak 1999). Southern populations may have a lower life span due to higher predation than northern populations (BCI and SBDN 2013). For a stable population not in decline, the annual survival rate has been estimated at 46% (Rice 1957). Young experience a high mortality of 12% for colonies over water (Foster et al. 1978), and 75% of pre-flight mortality has been reported to occur within the first week of life (Hermanson and Wilkins 1986).

**Threats**

Populations of southeastern bats have been reported as declining dramatically in recent years. For example, in Florida at least 18 maternity caves with around 400,000 adult females were once known, but 1992 surveys found only eight maternity caves with around 200,000 adult females (Gore and Hovis 1992). Species dependent on caves and mines such as the southeastern bat are greatly affected by disturbance during hibernation or maternity periods (Clark et al. 1998, Currie and Carolina 1999), and destruction of these roosts is a leading factor contributing to population declines (Humphrey 1975, Sheffield and Chapman 1992). Examples of human disturbance that have led to abandonment of caves by southeastern bats include vandals, careless cave explorers, blocking caves with rocks, setting guano piles on fire, and turning caves into dump sites (Rice 1957, Mount 1986, Gore and Hovis 1994). Disturbance to hibernacula causes bats to deplete their fat supplies and abandon caves, and disturbance to maternity colonies may lead adults to inadvertently knock young from the roost in their haste to leave, causing juvenile mortality (Foster et al. 1978, Hermanson and Wilkins 1986). Pesticide poisoning, especially by organochlorines and anticholinestrase, is a threat to this species because it has been shown to cause population declines in insectivorous bats (Geluso et al. 1976, Reidinger 1976, Brady et al. 1982). Pesticides can also alter behavior, cause mortality, and be transferred to nursing young (Clark 1981, 1986, Henny et al. 1982). Heavy metals may also be a threat (Bunch et al. 2015*b*), though survival rates in a Florida population were not affected when exposed to high levels of cadmium, lead, chromium, and zinc (Clark 1986).

Flooding has been known to kill 57,000 bats in Florida (Gore and Hovis 1994), and can be exacerbated by land use changes such as impoundments or channelization. Alteration of natural flood regimes may affect the regeneration of important forest community types such as cypress-gum, thus preventing recruitment of future roost trees (Bunch et al. 2015*b*).

Destruction and fragmentation of mature forests in the mountains and Coastal Plain and bottomland hardwood forests of South Carolina is another threat since this species depends on these areas for foraging and roosting (Bunch et al. 2015*b*). In fact, the loss of cypress and tupelo gum swamps, bottom-land hardwood and other forested wetlands has contribute to the decline of southeastern bats (Mirowsky and Horner 1997). Additionally, many of these habitat alterations can cause increased predation by natural predators.

WNS was confirmed in a southeastern bat for the first time in June of 2017 (USFWS 2017). Though more than 90% of bat populations from other species affected by the disease have declined since WNS was first detected, it is unknown how the disease will affect southeastern bats.

Other potential threats cited by Bunch et al. (2015*b*) include abundant invasive exotic vegetation, such as some privet species, that may prevent the regeneration of forest species and impair recruitment of suitable roost trees; genetic isolation of populations and feral cats as unnatural predators at roosts are threats to southeastern bats; and deforestation of oak (*Quercus* species) from Sudden Oak Death (SOD) caused by *Phytophthora ramorum*, which was recently detected on nursery stock in South Carolina, even though it has not been found in a natural setting to date.

Another threat to this species is the inadequacy of existing regulations for management of forestry, wind energy development, and oil, gas, and mineral extraction, especially when it comes to the protections afforded a state-listed species. These protections are meant to prevent trade or possession of state-listed species, but do not to protect against habitat destruction (USFWS 2011).

Additionally, small numbers of deadly collisions with towers in Florida have been recorded for this species (Crawford and Baker 1981). However, the level of impact from tower mortalities on either local or range wide populations remains unclear.

Global climate change could be a potential threat because it may make southern hibernation sites unsuitable due to increased temperatures (Bunch et al. 2015*b*).

**Conservation Measures**

Bat exclusion, not extermination, is the most effective and humane way to remove bats from buildings. Sealing out bats and/or adding more light to the roost of a colony are more effective alternatives than use of pesticides for control purposes (Laidlaw and Fenton 1971, Barclay et al. 1980). To minimize negative impacts to southeastern bats, eviction from buildings should include appropriately timed exclusion methods. To avoid the maternity period, bats should not be evicted from May through July. Alternatively, populations at the roost area may be decreased by 41 to 96% if lights are introduced to the area (Laidlaw and Fenton 1971). Measures should be taken to provide species-specific alternate roost structures before eviction, and structures that mimic large hollow trees such as large bat towers may be a suitable alternative for southeastern bats.

Other habitat protection and management recommendations from Bunch et al. (2015*b*) include working to protect mature bottomland hardwood forests and connecting corridors in the Inner and Outer Coastal Plain; recruit younger stages of high quality bottomland habitat for growth into future roost trees; prevent or reduce disturbance to natural and artificial roost structures, as well as to maternity colonies and hibernacula through gating, warning or interpretive signs, prevention of trails or roads to these sites, and other protective measures; retain and recruit cypress-gum swamp forests with large cavity trees; designate no-cut buffer zones around known roosts; provide forested corridors between harvested units; and protect foraging areas and migration corridors, which could be done through landowner incentive programs, conservation easements, lease agreements, or purchases. Other measures may include providing, protecting, and maintaining large diameter roost trees, large snags, decadent trees, hollow trees, and roost structures, especially near water or riparian areas; attempting to create or maintain patches of structurally diverse forest in order to provide a wide variety of suitable roosting and maternity sites; minimizing large-scale pesticide use whenever possible; and protecting habitat above or around maternity roosts and known foraging areas from pesticides. Also, using flashing lights instead of constant lights on towers, which is now regarded as acceptable by the FAA, can reduce bat mortality (Bunch et al. 2015*a*).

Priority survey and research recommendations from Bunch et al. (2015*b*) include working to determine if prescribed fire represents any threat, and also the acceptable distance of fire, smoke and fire lines from roosts; determine summer and winter roost site requirements; determine the genetic structure of selected colonies and test whether populations are experiencing adverse genetic consequences from isolation and fragmentation; survey and map mines, tunnels, wells and cave-like structures not surveyed in previous efforts; obtain long-term demographic data including reproductive success, sex ratios, survival, immigration and emigration facilitated by dispersal, and determine the effects of biotic and abiotic factors on these parameters; determine if unnatural predation at roosts by feral cats is occurring, including the southeastern bat roost at Orangeburg State Park; develop suitable human-made roosts specific to these species; use existing data on habitat preferences to identify the availability of natural roost habitat and to determine the amount of protected versus unprotected habitat; determine roosting habitat requirements including landscape factors that influence roost habitat quality; obtain basic information on colony size, composition, dynamics, and how these vary with roost site characteristics; identify colonies of southeastern bats and begin long-term monitoring on colony size, persistence, and roost sites; conduct seasonal surveys at caves and mines being considered for closure; evaluate roost and appropriate food (insects high in polyunsaturated fats) availability, as well as roost temperatures, and compare these factors with winter survival. Further research is greatly needed to identify the best placement of wind turbines, as well as strategies that would minimize impacts to bats (Ellison 2012). The SCDNR Heritage Trust tracks high priority species including the southeastern bat, and researchers are requested to submit bat data and occurrence records to their database.

Education and outreach goals recommended by Bunch et al. (2015*b*) include working to create general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans.

# Tricolored Bat (*Perimyotis subflavus*)

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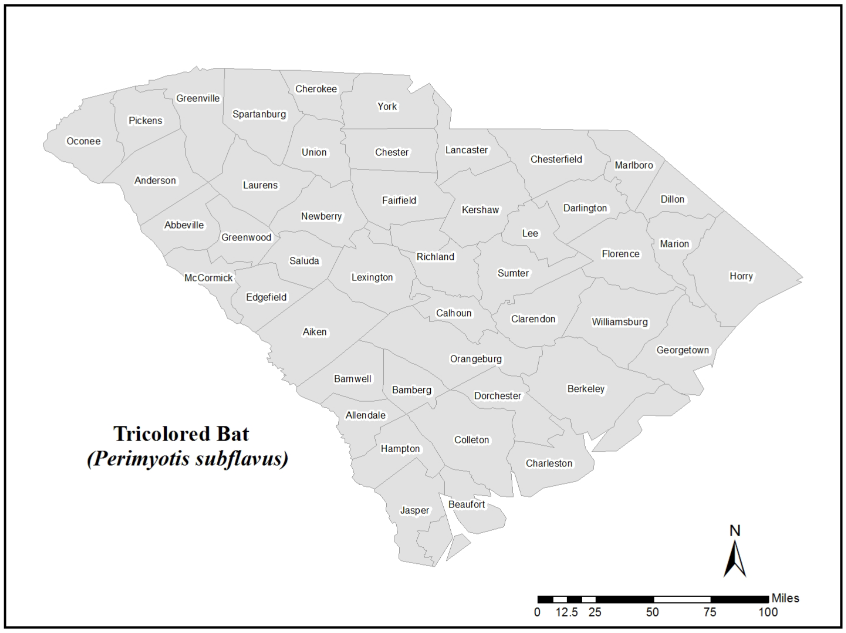
**Description**
The tricolored bat is a common bat found throughout the forests of the eastern US, and is the second smallest bat found in South Carolina (J. M. Menzel et al. 2003). Before the Genus was changed to *Perimyotis*, it was formerly known as the eastern pipistrelle (*Pipistrellus subflavus*). While hibernating, this species is often found covered in condensation. Unfortunately, populations of tricolored bats have declined greatly due to the effects of WNS since 2006 (Francl et al. 2012, Langwig et al. 2012). The first case of WNS in South Carolina was confirmed on a tricolored bat found at Table Rock State Park in March of 2013. In 2014, two other cases on tricolored bats were confirmed as positive for WNS via histopathology, one of which was discovered at the Stumphouse Mountain Heritage Preserve in Oconee County, and another case in Richland County.

**Identification**
The tricolored bat is a small bat weighing 0.2 to 0.3 ounces (5 to 8 gr) and has a wingspan of 8 to 10 inches (21 to 26 cm) (Harvey et al. 2011). An obvious identifying characteristic of this species is the pink color of the skin on the radius bone. The term "tricolored" refers to the yellowish-brown pelage whose hairs are dark at the base, yellowish-brown in the middle, and dark at the tips. The calcar is unkeeled, and the base of the underside of the interfemoral membrane is furred. The wing membranes are blackish, but the face and ears have a pinkish color. The tragus is straight, long, and rounded, and the feet are relatively large compared to body size.

**Taxonomy**
Currently there are four recognized subspecies of the tricolored bat (Wilson and Reeder 2005), and only *Perimyotis subflavus subflavus* occurs in South Carolina (Fujita and Kunz 1984).

**Distribution**
The tricolored bat is distributed from eastern Canada south through most of the eastern US and into Mexico, and west to Michigan, Minnesota and Texas. Before WNS was detected, the range of this species was expanding westward from South Dakota to Texas and New Mexico (Geluso et al. 2005) and northward into the central Great Lakes region (Kurta et al. 2007). In South Carolina, they are distributed statewide and found in all four physiographic provinces (M. A. Menzel et al. 2003).

**Population Status**
The tricolored bat has a rounded rank of Globally Imperiled (G2G3), Nationally Vulnerable (N3N4) and Subnationally Unranked (SNR) (NatureServe 2017). However, it is currently ranked as Subnationally Critically Imperiled (S1S2) by the SCDNR Heritage Trust (see Table 2). It is currently classified as Least Concern (LC) on the IUCN Red List (Arroyo-Cabrales et al. 2008*c*). The tricolored bat was considered relatively common throughout the state, however hibernating populations have




recently been affected by WNS and are currently in decline. This species is listed as a Highest Priority species in the South Carolina 2015 SWAP (SCDNR 2015).

**General Habitat**

Tricolored bats are associated with forested landscapes, often in open woods and found over water and adjacent to water edges (Fujita and Kunz 1984, Schmidly 1991, Nowak 1999). In South Carolina, sparse vegetation and early successional stands were found to be the best predictor of foraging habitat use by tricolored bats (Loeb and O'Keefe 2006).

**Roosts and Roosting Behavior**

Summer maternity roosts and winter hibernacula are usually located in different areas (Amelon 2006). During summer, this species is known to use caves, rock crevices, tree foliage, Spanish moss and buildings as roosts (Schmidly 1991, Menzel et al. 1999*a*, Nowak 1999, Briggler and Prather 2003). More than one roost location may be used by summer roosting groups (Whitaker and Hamilton 1998), and individuals roosting in buildings are known to commonly switch roosts (Ammerman et al. 2012). Additionally, caves with high humidity may be chosen as a summer roost by both males and females in arid regions (Caire et al. 1984). In South Carolina, this species has been found in the cavities of bottomland hardwood tree species such as swamp chestnut oak (*Quercus michauxii*), sweetgum, and laurel oak (*Q. laurifolia*) (Carter et al. 1999), as well as in Spanish moss in understory trees on exposed high-marsh hammocks (Menzel et al. 1999*a*). A colony was also found in the attic of a garage in Oconee County (Golley 1966). Evidence of tricolored bats in the southern Appalachian Mountains indicated that they preferred roosts near streams (O'Keefe et al. 2009).

Maternity roosts are found in human-made structures such as houses and barns (Allen 1921, Poole 1938, Lane 1946), ammunition storage bunkers (Jones and Pagels 1968, Jones and Suttkus 1973), and road culverts (Sandel et al. 2001), but may also include trees (Humphrey 1975), caves (Humphrey et al. 1976), rock crevices (Barbour and Davis 1969, Fujita and Kunz 1984), and even squirrel nests (Veilleux et al. 2003). Veilleux et al. (2003) found that 19 reproductive tricolored bats in Indiana preferred oaks as roost trees, and roosted exclusively in foliage, with 65% in clusters of dead leaves, 30% in live foliage, and 5% in squirrel nests. In this study, they also found the mean roost tree height to be around 68 feet (20.8 m), the roost height from the ground to be 52 feet (15.7 m), and the roost tree diameter at breast height to be 13 inches (33.2 cm). Females roost in maternity colonies with an average of 15 individuals, or up to 50 (Perry and Thill

2007*c*), and some observations suggest roost switching may be common during the maternity period (Whitaker and Hamilton 1998). Reproductive tricolored bats have been known to stay at roost trees for an average of six days before travelling between 62 to 456 feet (19 and 139 m) to another roost site carrying their young (Nowak 1999, Veilleux et al. 2003). The mean maximum distance moved between roost locations for this species in the southern Appalachian Mountains was 1,968 ± 738 feet with a range of 46.9 to 5, 964.2 feet (600 ± 225 m; range 14.3–1817.9 m) (O'Keefe 2009). However, some evidence from reproductive females in Indiana suggests that this species may have site fidelity to small roost areas within and between years (Veilleux and Veilleux 2004).

Like the eastern red bat, tricolored female bats may have higher temperature demands for birthing and nursery conditions and be restricted to lower elevations associated with higher temperatures during summer in the eastern US (Ford et al. 2002). During periods of low temperatures, females may enter torpor and reduce milk and energy output to the pups, which may contribute to reduced growth rates (Hoying and Kunz 1998). Males roost alone during the summer (Whitaker and Hamilton 1998), and fidelity to roost sites is relatively high as evidenced by the fact that they have been recorded as using the same foliage roost for up to 33 days (Whitaker and Hamilton 1998, Perry and Thill 2007*c*). In South Carolina, basal cavities may serve as maternity roosts for tricolored bats (Menzel et al. 1996). In South Carolina and Indiana, females form maternity colonies of three to five individuals in clusters of live or dead leaves in trees (Bunch et al. 2015*b*). Males in North Carolina are known to use large diameter oaks and hickories for roosts, and use trees taller than the nearest tree but not necessarily the tallest tree in the plot area (O'Keefe et al. 2009, Bunch et al. 2015*b*).

During winter, tricolored bats are obligate hibernators even when food is available in warmer climates (Briggler and Prather 2003), and they rarely leave hibernacula during this time (Whitaker and Rissler 1992*b*). Hibernacula include highway culverts (Walker et al. 1996, Sandel et al. 2001), tunnels (Mohr 1942), storm sewers (Goehring 1954), caves (Hahn 1908, Swanson and Evans 1936, Reite and Davis 1966, Raesly and Gates 1987) and mines (Sealander and Heidt 1990, Whitaker and Rissler 1992*b*, Menzel et al. 1997). This species may be one of the earliest bats to arrive to hibernacula and the last to leave (LaVal and LaVal 1980), and bats tend to stay in deep torpor for longer periods of time (maximum recorded at 11 days, (Twente et al. 1985)) than other temperate hibernating bats between arousals from hibernation (Amelon 2006). Beginning in late July through October, males and females may roost in the same hibernacula, generally hibernating singly, and disperse again in early April (Griffin 1940, Fujita and Kunz 1984, Schmidly 1991). Factors that contribute to the selection of hibernacula include east-facing openings and the distance and abundance of the nearest forest available (Sandel et al. 2001, Briggler and Prather 2003), as well as standing water and mine entrance size and gradient (Menzel et al. 1999*a*). Tricolored bats also frequently use locations deep within hibernacula where temperatures are stable, humidity is high, and airflow is minimal (Hitchcock 1949, Rabinowitz 1981, Caire et al. 1989). Site fidelity to hibernacula for this species is relatively high, at 30 to 60% (Hahn 1908, Menzel et al. 1999*a*). Night roosts include caves, mines, and rock crevices (Barbour and Davis 1969). In South Carolina, tricolored bats are consistently found in abandoned mines and incomplete Blue Ridge Railroad tunnels in the mountains during winter hibernacula surveys (Bunch et al. 2015*b*). Golley (1966) reported a tricolored bat roosting under a house in Berkeley

County, as well as a large colony roosting in caves in Orangeburg County. However, there have been no studies quantitatively examining winter roosting habits for this species in the state.

**Reproduction**

Mating occurs between August and October and again during ovulation in spring, and sperm is stored in the female's uterus until spring when fertilization takes place (Guthrie 1933, Whitaker and Hamilton 1998). Twins are usually born from June to mid-July in northern portions of this species range, and May through June in the southern portions (Fujita and Kunz 1984, NatureServe 2017). Gestation lasts 44 days (Wimsatt 1945), young begin to fly at three weeks (Lane 1946, Hoying 1983), and are weaned at four weeks (Whitaker and Hamilton 1998). Depending on environmental conditions, sexual maturity may be attained between 3 and 15 months (Krutzsch and Crichton 1986, Hoying and Kunz 1998).

**Food Habits and Foraging**

The tricolored bat is one of the earliest bats to emerge at night (Fujita and Kunz 1984), and is thought to feed until midnight and again near dawn (Amelon 2006). This species has a relatively slow, erratic flight pattern, low wing loading, and a higher aspect ratio that reflect their longer, more pointed wings (Farney and Fleharty 1969, Paradiso 1969, Hoying and Kunz 1998). Tricolored bats are considered a clutter-adapted species, but are also well adapted to foraging in open habitats, canopy gaps, edge habitats, and along waterways of forest edges (Barbour and Davis 1969, Fujita and Kunz 1984, Veilleux et al. 2003). This species has been recorded feeding over the top of streamside vegetation and taller streamside trees (Caire et al. 1984, Harvey et al. 1999*a*), however, their activity did not differ above, within, or below the forest canopy in a South Carolina study by Menzel et al. (2005). Tricolored bats appeared to primarily use areas of unfragmented forest cover in Nova Scotia (Farrow and Broders 2011). Most foraging activity tends to occur in riparian areas, as seen in studies in Georgia (Ellis et al. 2002), South Carolina (Menzel et al. 2005*b*), and an Appalachian forest in West Virginia (Ford et al. 2005). Bottomland hardwoods and pine stands have been reported as foraging areas at the Savannah River Site in South Carolina (Carter et al. 1999), and at the same study location Menzel et al. (2003*b*) reported the greatest activity around lakes and ponds, bottomland hardwood forests, and grass-brush habitats. In forest stands of different ages, Menzel et al. (2003*b*) recorded the most activity in clearcuts, (as well as roads and open water habitats) with moderate activity in stands four to 20 years old. However, tricolored bats in the southern Appalachian Mountains only used stands greater than or equal to 72 years in age at an average elevation of 2,893 feet (882 m) (O'Keefe et al. 2009). In relation to fire treatments in South Carolina, Loeb and Waldrop (2008) found the activity of tricolored bats did not vary significantly between thinned, burned, or the control tree stands. Some female tricolored bats in Indiana have been found foraging up to 2.6 miles (4.2 km) away from roost locations (Veilleux et al. 2003), while the distance traveled from roosting areas to foraging locations in Georgia averaged 0.7 miles (1,137 m) (Krishon et al. 1997). In South Carolina, the activity of tricolored bats has been recorded widely around Lake Jocassee and Lake Keowee, in April, July and October at all of the 31 sites surveyed (Webster 2013).

Considered a generalist insectivore, the tricolored bat consumes Coleoptera, Diptera, Hemiptera, Homoptera, Hymenoptera, Lepidoptera, and Trichoptera ranging in size from 0.16 to 0.4 inches (4 to 10 mm) in length (Whitaker 1972, Griffith and Gates

1985, Brack Jr. and Finni 1987, Carter et al. 2003). Compared to the relative availability of prey in a study in Georgia, lepidopterans where preferred while coleopterans and homopterans were selected for less than what might be expected based on availability (Carter et al. 1998).

The home range of tricolored bats has been reported as 961 acres (389 ha) in Georgia, and 978 acres (396 ha) in South Carolina (Krishon et al. 1997, Carter et al. 1999). The habitats within the home range in Georgia were comprised of 47% high-marsh, 24% oak (*Quercus* species), and 17% loblolly-slash pine (*Pinus taeda, Pinus elliottii*) (Krishon et al. 1997).

**Seasonal Movements**
The tricolored bat is known to be a latitudinal and regional migrant as well as a long-distance migrant in northern populations (Fraser et al. 2012, NatureServe 2017). Banded individuals have been reported as making regional migrations up to 85 miles (136 km) (Griffin 1940, Barbour and Davis 1969). In the southern portion of its range, males have been shown to have a southern fall migration (Fraser et al. 2012). Populations in the mountains of South Carolina may migrate, but otherwise tricolored bats are thought to be resident to the state.

**Longevity and Survival**
The oldest tricolored bat was recorded at nearly 15 years old, though the lifespan of this species in the wild is four to eight years (Walley and Jarvis 1971, Whitaker and Hamilton 1998, Nowak 1999). High mortality has been reported to occur between the first and second hibernation period, and for juveniles is especially high during the second summer (Davis and Hitchcock 1965, Reite and Davis 1966). Survival rates have been reported as being higher in males than females (Amelon 2006).

**Threats**
WNS is a major threat to tricolored bats because populations of this species have already declined greatly since 2006 due to its effects (Francl et al. 2012, Langwig et al. 2012).

Disturbance or destruction of natural and artificial roost structures pose additional major threats to this species, especially to hibernacula and maternity roosts (Amelon 2006). Many forms of habitat alteration can also cause increased predation by natBural predators (Bunch et al. 2015*b*).

Wind turbines pose a threat to tricolored bats, especially if erected near roosts, colony sites, and along migratory pathways, as mortalities have been reported at multiple wind-energy facilities in the US (Ellison 2012). This species is frequently killed by wind turbines, and deaths may account for up to 25% of total bat deaths (Arnett et al. 2008). For example, tricolored bats where one of six bat species killed at a wind power development at Buffalo Ridge, Minnesota (Johnson et al. 2003), and were one of the top three species with the highest total mortality at the Buffalo Mountain Windfarm in Tennessee (Fiedler 2004). No wind turbines have been placed in South Carolina to date, however, Clemson University is constructing a test facility for turbines at the coast (Bunch et al. 2015*b*).

Pesticide poisoning, especially by organochlorines and anticholinestrase, is a threat to this species because it has been shown to cause population declines in insectivorous bats (Geluso et al. 1976, Reidinger 1976, Brady et al. 1982). Pesticides can also alter behavior, cause mortality, and be transferred to nursing young (Clark 1981, 1986, Henny et al. 1982).

Deforestation of oak (*Quercus* species) from Sudden Oak Death (SOD) disease caused by the plant pathogen *Phytophthora ramorum* may pose a threat to habitats critical to forest-dwelling bats. Though it has not been found in a natural setting to date, this disease was recently detected on nursery stock in South Carolina (Bunch et al. 2015*b*)

Global climate change is a potential threat to tricolored bats because it may make southern hibernation sites unsuitable due to increased temperatures (Bunch et al. 2015*b*).

**Conservation Measures**

Bat exclusion, not extermination, is the most effective and humane way to remove bats from buildings. Sealing out bats and/or adding more light to the roost of a colony are more effective alternatives than use of pesticides for control purposes (Laidlaw and Fenton 1971, Barclay et al. 1980). To minimize negative impacts to tricolored bats, eviction from buildings should include appropriately timed exclusion methods. To avoid the maternity period, bats should not be evicted from May through July. Alternatively, populations at the roost area may be decreased by 41 to 96% if lights are introduced to the area (Laidlaw and Fenton 1971). Measures should be taken to provide species-specific alternate roost structures before eviction, and typical bat boxes may be a reasonable alternative for tricolored bats.

Other habitat protection and management recommendations from Bunch et al. (2015*b*) include working to prevent or reduce disturbance to natural and artificial roost structures, as well as to maternity colonies and hibernacula through gating, warning or interpretive signs, prevention of trails or roads to these sites, and other protective measures; retain and recruit cypress-gum swamp forests with large cavity trees; designate no-cut buffer zones around known roosts; provide forested corridors between harvested units; and protect foraging areas and migration corridors, which could be done through landowner incentive programs, conservation easements, lease agreements, or purchases. Other measures may include providing, protecting, and maintaining large diameter roost trees, large snags, decadent trees, hollow trees, and roost structures, especially near water or riparian areas; attempting to create or maintain patches of structurally diverse forest in order to provide a wide variety of suitable roosting and maternity sites; minimizing large-scale pesticide use whenever possible; and protecting habitat above or around maternity roosts and known foraging areas from pesticides.

Priority survey and research recommendations from Bunch et al. (2015*b*) include conducting seasonal surveys at caves and mines being considered for closure; and evaluating roost and appropriate food (insects high in polyunsaturated fats) availability, as well as roost temperatures, and compare these factors with winter survival. Further research is greatly needed to identify the best placement of wind turbines, as well as strategies that would minimize impacts to bats (Ellison 2012). The SCDNR Heritage Trust tracks high priority species including the tricolored bat, and researchers are requested to submit bat data and occurrence records to their database.

Education and outreach goals recommended by Bunch et al. (2015*b*) include working to create general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans.