Chapter 1: Status and Conservation Issues

Legal and Conservation Status

All South Carolina bat species are protected on public lands, including those managed and/or owned by both State and Federal resource agencies such as state wildlife management areas, heritage preserves, and national forests. Additional protection may be provided on lands owned or operated by non-profit conservation organizations such as The Nature Conservancy, National Audubon Society, and local and national Land Trust Organizations.

Federal

Of the 14 bat species in South Carolina, none are federally listed as endangered, one is federally listed as threatened with an 4(d) rule (northern long-eared bat), two are being evaluated by the USFWS to determine if listing under the ESA is warranted (little brown bat and tricolored bat), and three are considered at-risk species by the agency (eastern small-footed bat, Rafinesque's big-eared bat, and tricolored bat) (Table 2).

In June of 2011, a status review of the eastern small-footed bat and the northern long-eared bat was initiated. In October 2013, the USFWS announced a 12-month finding on a petition to list the eastern small-footed bat and the northern long-eared bat as endangered or threatened under the ESA and found that the eastern small-footed bat did not warrant listing (USFWS 2013) but proposed a status of Endangered for the northern long-eared bat due to threats from WNS. In April 2015 it was determined the northern long-eared bat met the ESA definition of Threatened, and 30 days later the listing became effective with an 4(d) rule providing flexibility to specific entities who conduct activities in northern long-eared bat habitat (USFWS 2015*a*). In April 2016, the US Fish and Wildlife Service determined that designating critical habitat for northern long-eared bats was not prudent, however this species is still listed as threatened under the ESA (USFWS 2016). In January of 2020, the U.S. District Court for the District of Columbia resolved a challenge by the Center for Biological Diversity, ruling that the USFWS violated the endangered species act by listing the northern long-eared bat as threatened. Currently, the USFWS is reevaluating that listing as part of this ruling.

Currently, a USFWS petition for the little brown bat (Kunz and Reichard 2010) is under review for a 12-month finding to be completed by the 2023 fiscal year. A 90-day finding determined that action may be warrented and is being evaluated for the tricolored bat (Center for Biological Diversity and Defenders of Wildlife 2016).

Federally threatened northern long-eared bat and 4(d) rule exemptions

The following information from the USFWS (2015) applies to projects that could result in take (defined by the ESA as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct") of northern long-eared bats within the range of the northern long-eared bat and the WNS Buffer Zone (see map at https://www.fws.gov/Midwest/endangered/mammals/nleb/pdf/WNSZone.pdf). South Carolina counties within these areas include Abbeville, Anderson, Beaufort, Berkeley, Charleston, Cherokee, Greenville, Laurens, Oconee, Pickens, Spartanburg, Union, and York. Though the section below attempts to explain the 4 (d) rule, federal agencies that carry out, fund, or authorize projects that may affect northern long-eared bats are required to

Table 2: Federal and state conservation status of bat species in South Carolina.

		Federal	State		
Common Name	**Scientific Name**	**USFWS[a]**	**SCDNR[b]**	**SCDNR Heritage Trust[c]**	
Big Brown Bat	*Eptesicus fuscus*		SGCN	G5	S5?
Brazilian Free-tailed Bat	*Tadarida brasiliensis*			G5	S4S5
Eastern Red Bat	*Lasiurus borealis*		SGCN	G3G4	S4S5
Eastern Small-footed Bat	*Myotis leibii*	ARS	ST, SGCN	G4	S1
Evening Bat	*Nycticeius humeralis*			G5	S5
Hoary Bat	*Lasiurus cinereus*		SGCN	G3G4	SNR
Little Brown Bat	*Myotis lucifugus*		SGCN, *	G3	S1S2
Northern Long-eared Bat	*Myotis septentrionalis*	T	SGCN, *	G1G2	S1
Northern Yellow Bat	*Lasiurus intermedius*		SGCN	G5	SNR
Rafinesque's Big-eared Bat	*Corynorhinus rafinesquii*	ARS	SE, SGCN	G3G4	S2
Seminole Bat	*Lasiurus seminolus*		SGCN	G5	S4?
Silver-haired Bat	*Lasionycteris noctivagans*		SGCN	G3G4	SNR
Southeastern Bat	*Myotis austroriparius*		SGCN, *	G4	S1S2
Tricolored Bat	*Perimyotis subflavus*	ARS*	SGCN, *	G2G3	S1S2

[a]U.S. Fish and Wildlife Service: E = Federally Endangered, T = Federally Threatened, ARS = At-Risk Species that the FWS has been petitioned to list and for which a positive 90-day finding has been issued (listing may be warranted); information is provided only for conservation actions as no Federal protections currently exist, ARS* = At-Risk Species that are either former Candidate Species or are emerging conservation priority species.

[b]South Carolina Department of Natural Resources: SE = State Endangered, ST = State Threatened, SGCN = Species of Greatest Conservation Need, * = State Endangered or State Threatened has been proposed.

[c]NatureServe: G = global, S = state, 1 = critically imperiled, 2 = imperiled, 3 = vulnerable to extirpation or extinction, 4 =apparently secure, 5 = demonstrably widespread, abundant, and secure. Rankings taken from Master et al. 2012.

have a formal USFWS consultation. A formal consultation is not required only if a federal action agency determines that no effect to northern long-eared bats is expected. For more information, please contact Morgan K. Wolf at (843) 727-4707 ext. 219, or morgan_wolf@fws.gov at the USFWS Charleston office. Section 9 of the Endangered Species Act prohibits take of a wildlife species listed under the ESA as threatened unless specifically authorized by regulation. Any purposeful take of northern long-eared bats for removal from a human structure, or by individuals authorized to conduct capture or related activities for other bats listed under the Endangered Species Act within one year of the effective date of the 4(d) rule, are exempted by the 4(d) rule. To clarify, this means that no permit or consultation is required to exclude northern long-eared bats from a home. Researchers and biologists conducting actions relating to capture, handling, attachment of radio transmitters, and tracking of northern long-eared bats will be required to obtain a federal scientific collection/recovery permit under Section 10(a)(1)(A) of the ESA.

Incidental take of northern long-eared bats is allowed for actions outside of the WNS Buffer Zone (see map above). Incidental take within the WNS buffer zone not related to specific forest management, native prairie management, minimal and hazardous tree removal, and maintenance or expansion of existing rights-of-way and transmission corridors, as outlined in the 4(d) rule, are not exempted by the 4(d) rule and may require an incidental take permit under Section 10(a)(1)(B) of the ESA. Forest management that converts mature hardwood, or mixed, forest into intensively managed monoculture pine plantation stands, or non-forested landscape, is not exempted under the 4(d) rule since these plantations provide poor-quality bat habitat. Minimal tree removal only refers to an impact of one acre or less of contiguous habitat or one acre total within a larger tract. If a northern long-eared bat maternity roost tree or hibernacula has been documented on or near the project area for forest management, native prairie management, minimal and hazardous tree removal, and maintenance or expansion of existing rights-of-way and transmission corridors projects, incidental take will be exempted by the 4(d) rule if activities are not conducted within ¼ mile of known, occupied hibernacula; a known, occupied roost tree from June 1 to July 31 (during the pup season) is not cut or destroyed; and clearcuts are not conducted within a ¼ mile of known, occupied roost trees from June 1 to July 31. Otherwise, an incidental take permit under Section 10(a)(1)(B) of the ESA may be necessary for these activities.

Caves on federal land

Significant caves on federal lands are secured, protected, and preserved by federal land managers through the Federal Cave Resources Protection Act of 1988 (18 U.S.C. § 4301–4309). Caves on federal land generally fulfill the "significant" cave definition, meaning those with characteristics pertaining to biological, geological, mineralogical, paleontological, hydrological, cultural, recreational, educational, or scientific resources. Specific locations of caves and mines are not disclosed for their protection (16 U.S.C § 4304(a)). Additionally, in 2014 the US Forest Service (USFS) authorized continued closure to human entry of all caves and abandoned underground mines in the Southern Region for five years in order to protect caves, mines, and/or associated wildlife species from the spread of *Pseudogymnoascus destructans*, the fungal agent causing WNS, through human transmission (USFS 2014).

State

One bat species in South Carolina is state endangered (Rafinesque's big-eared bat), and one is a "species in need of management" or equivalent to state threatened (eastern small-footed bat). A total of twelve, or 86% of South Carolina's bat species, are on the list of South Carolina's "Species of Greatest Conservation Need" and considered "Highest Priority" in the South Carolina State Wildlife Action Plan (SCDNR 2015) (Table 2). This high proportion is not limited to South Carolina as 15 years ago, before WNS was even detected, 87% of bat species in the Southeast had special conservation designations (Laerm et al. 2000).

State endangered and state threatened bat species are protected under the South Carolina Nongame and Endangered Species Conservation Act (§50-15-10 et seq.). For

State endangered species (CL 50-15-30(C), Appendix A), violation of the law is a misdemeanor and a fine of $1,000 or imprisonment up to a year, or both (CL 50-15-80(B), Appendix A). There is less stringent protection for species recognized as state threatened or species "in need of management" (CL 50-15-20(C), Appendix A). This designation roughly parallels the federal threatened species statute and establishes South Carolina Department of Natural Resources (SCDNR) as the authority to engage in conservation activities and develop management programs so these species can "sustain themselves successfully." Violation of this law is a misdemeanor, a fine of up to $500 or imprisonment up to 30 days, and restitution paid (CL 50-15-80(A), Appendix A).

The collection of any bat species in South Carolina for scientific or propagating purposes requires a scientific permit (CR 123-150.3, Appendix A). Violation of the law is a misdemeanor and a fine of between $25 and $100, imprisonment up to 30 days, and revocation of the permit (CL 50-11-1180, Appendix A).

Any bat species may be removed from a home in South Carolina without a permit or consultation. If it is necessary to protect human health and there is no immediate threat to human life, a permit may be issued to remove, capture, or destroy an endangered species. In the case of an immediate threat to human life, no permit is required to remove, capture, or destroy threatened or endangered or species in need of management (CL 50-15-40(E), Appendix A). Additionally, the department may permit taking, possession, transportation, exportation, or shipment of species which appear on the state list of endangered species, or federal list of threatened or endangered species, for scientific, zoological, or educational purposes, for propagation in captivity of such wildlife, or for other special purposes (CL 50-15-40(D), Appendix A).

All South Carolina bats are protected on Heritage Preserves and SCDNR owned lands (CL 50-11-2200 (C), Appendix A). Violation of the law is a misdemeanor, and may require restitution to the land owner, a fine of between $200 and $500 or imprisoned for up to 30 days or both, loss of privilege to enter these lands for two years, and loss of privilege to hunt and fish for one year (CL 50-11-2210, CL 50-11-2220, Appendix A).

The Heritage Trust Program of the SCDNR protects critical natural habitats and significant cultural sites in the form of heritage preserves. This program identifies conservation ranks for South Carolina bat species according to NatureServe criteria, which can be seen in Table 2.

Public Health

Rabies

Rabies is a viral disease transmitted through mammals that infects the central nervous system and is fatal to humans if not treated early. The vast majority of cases reported annually occur in raccoons, skunks, foxes, and insectivorous bats (Center for Disease Control 2015). Transmission usually occurs when infected saliva of a host is passed through bites and scratches, though there have been very rare cases of infected saliva coming into contact with mucous membranes (i.e., eyes, nose, mouth) (Brass 1994). If a suspected or confirmed rabies exposure occurs, development of rabies can be prevented by immediately contacting a doctor and the local health department, and the individual will be treated with a series of intramuscular injections of postexposure prophylaxis of human antirabies immunoglobulin over a 14-day period. For people who handle bats or come into regular contact with wild and feral mammals, such as veterinarians, animal control officers, wildlife biologists and rehabilitators, a preexposure prophylaxis is recommended (Krebs et al. 1995).

In the U.S. annually, the average number of people that die from rabies is one to two, and the animal that caused the infection is not known in the majority of cases. Deaths from rabies in the U.S. often happen because individuals aren't aware of their exposure and don't seek prompt post-exposure treatment. Particularly in developing countries, humans are typically exposed to rabies through unvaccinated dogs and cats. In the U.S., vaccination of dogs has led to a major decline of rabies cases in humans since the 1940s (Brass 1994), and today rabies is limited mostly to contact with wild animals. Exposure to infected bats accounts for many of these wild animal cases since the 1980s (Hoff et al. 1993, Childs et al. 1994, Krebs et al. 1995), and in recent years the proportion of rabies cases from bat bites has increased (Rupprecht et al. 2001). Rabies strains in bats differ from those in terrestrial mammals, meaning it's possible to determine routes of human exposure by animal type. Most human deaths from rabies have been found to be from unrecognized exposure to animals infected with bat-variant rabies (Messenger et al. 2003). In the U.S. from 1980 to 1994, 11 of the 14 confirmed cases of human rabies were linked to bats, eight of which were associated with the rabies virus variant in silver-haired bats (Krebs et al. 1995). Big brown bats, little brown bats, and tricolored bats are species found in South Carolina that could potentially carry this silver-haired bat rabies viral strain (Messenger et al. 1997). Rabies has also been documented in most other bat species occurring in the state, including hoary bat, eastern red bat, northern yellow bat, Seminole bat, eastern small-footed bat, southeastern bat, evening bat, silver-haired bat, Brazilian free-tailed bat, and Rafinesque's big-eared bat (Constantine 1979*a*, J. M. Menzel et al. 2003, Sasse and Saugey 2008). The Centers for Disease Control and Prevention statistics have indicated that only about 10% of all annually reported and confirmed rabid animals are from bats (Krebs et al. 1995). This statistic holds true for South Carolina, as of the 613 animals that tested positive for rabies in the state from 2010 to 2014, 51% were raccoons, 17% skunks, 15% foxes, 8% bats, 5% cats, 2% dogs, and 1% other wild animals (SCDHEC 2014). In a study looking at the distribution of bats species submitted for rabies testing between 1970 and 1990 in South Carolina, 231 out of 2,657 bats submitted were found to be rabid. The eastern red bat was submitted most frequently for testing (30%), and had the highest prevalence of rabies (18%) (Parker et al. 1999). However, bats turned in to be tested compared to those randomly sampled from the environment show very different rates of rabies prevalence, and depends on bat species, colony, and location (Brass 1994, Klug et al. 2011). Klug et al. (2011) studied bat species with the highest reported prevalence of rabies in North America, the hoary bat and the silver-haired bat, and compared bats turned in by the general public to random samples. They discovered that overall rabies prevalence is actually less than or equal to 1%. Though fears and misconceptions about health risks from rabies have resulted in unnecessary eradication (Pierson 1998), the overall human health risks posed by rabid bats in North America is very low and unprovoked attacks by rabid bats on humans is incredibly rare (Constantine 1979*b*, Tuttle and Kern 1981, Krebs et al. 1995, Rotz et al. 1998).

Most routes of contact and potential rabies transmission can be avoided by simple preventive measures. The majority of contact between humans and sick bats occurs when cats bring bats home to their owners (Constantine 2009), and species such as big brown bats that occur in or near buildings may pose a greater risk of rabies transmission to humans (Childs et al. 1994). Preventative measures that reduce the risk of rabies exposure include ensuring dogs and cats are vaccinated against rabies, avoiding handing wildlife, avoiding entry into caves, attics, or abandoned buildings that contain bats, preventing bats from roosting in buildings, and evicting bats through exclusion methods instead of chemical poisons. For a useful guide to bat exclusion, see Bats in Buildings: A Guide to Safe & Humane Exclusions by Bat Conservation International (https://www.batcon.org/pdfs/education/fof_ug.pdf).

Histoplasmosis

Histoplasmosis is a potentially fatal disease affecting the lungs caused by *Histoplasma capsulatum*, a fungus known to thrive in moderate temperatures and moist environments. Spores of this fungus are found in soil with bat or bird droppings, and when the soil is disturbed the spores may be readily released into the air, causing infection through inhalation of the contaminated soil. Symptoms are similar to those associated with the flu and include fever, chills, headache, muscle aches, dry cough, and chest discomfort. The disease can be fatal to infants and individuals with compromised immune systems such as older adults, or to those who may receive high doses such as farmers, cave explorers, or guano miners (De Monbreun 1934, Emmons 1949, American Lung Association 2015).

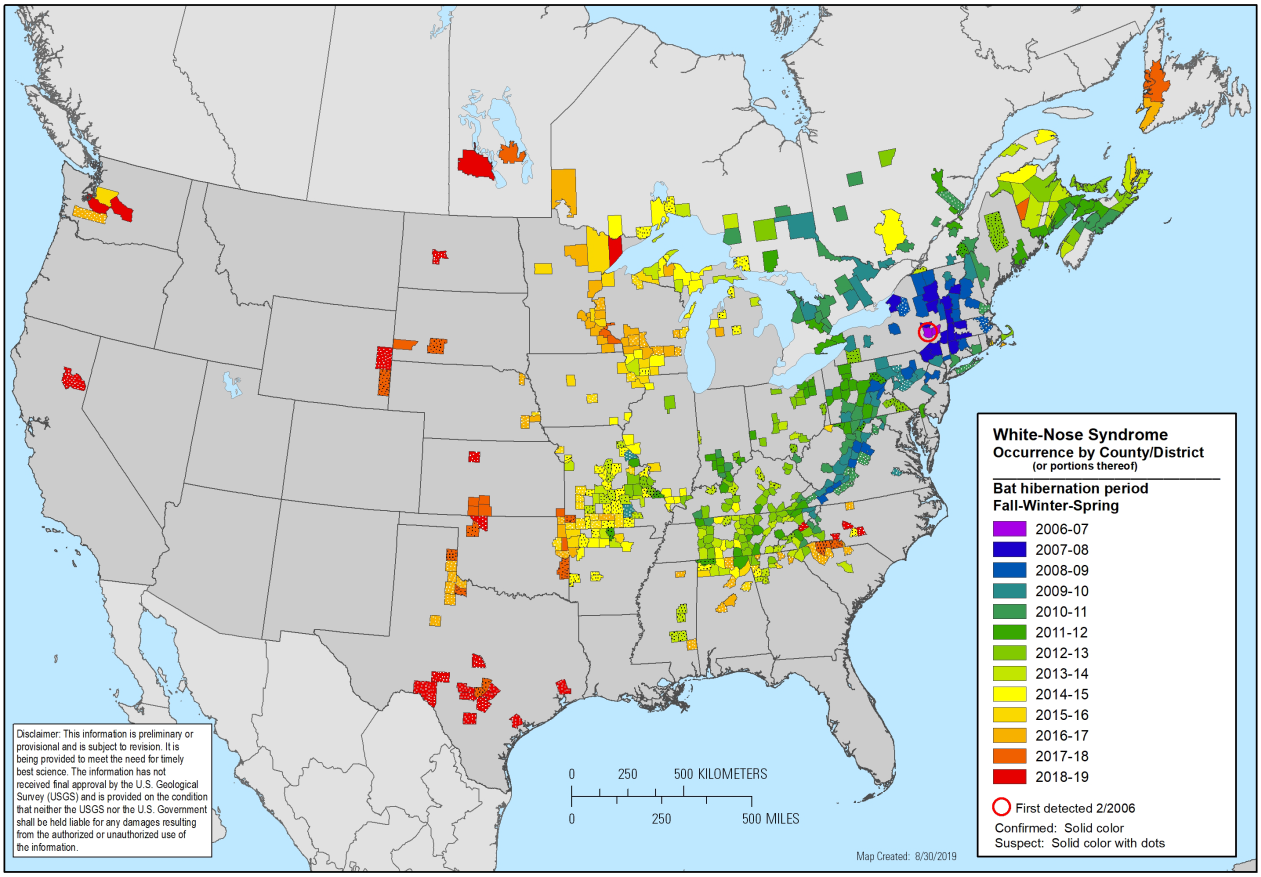
Histoplasmosis is endemic to South Carolina, and in 1979 an outbreak of 10 cases of histoplasmosis occurred following the clearing of a blackbird roosting area (DiSalvo and Johnson 1979). However, the disease is most commonly found in areas surrounding the Ohio and Mississippi River valleys and rates are highest in the Midwest, especially among older adults (Baddley et al. 2011). Preventative measures include avoiding exposure, spraying contaminated soil, and/or using a well-fitting respirator capable of filtering particles with a diameter of two microns (Constantine 1993). Persons working in bat guano should consult the Center for Disease Control website at http://www.cdc.gov/fungal/diseases/histoplasmosis/.

Conservation Issues

White-nose Syndrome

White-nose Syndrome (WNS) is a disease caused by a white fungus species *Pseudogymnoascus* (formally *Geomyces*) *destructans (Pd)* that forms on the nose, wing membranes, and ears of affected hibernating bats. A bat may be infected with WNS and not show signs of fungal growth, so histopathology may be required to confirm the disease (Meteyer et al. 2009). This fungus erodes the outer epidermis and infects underlying skin and connective tissue, causing inflammation. Hypotheses from the ultimate cause of mortality from WNS include the inability to function normally due to skin and wing damage (Cryan et al. 2010), shorter torpor bouts leading to the premature burning of fat reserves and causing starvation (Reeder et al. 2012), or increased evaporative water loss and dehydration (Willis et al. 2011) which could also lead to starvation from frequent waking due to thirst. However, a recent paper by Verant et al. (2014) suggests that fat reserves are prematurely burned before wing lesions or aberrant behavior such as shorter torpor bouts occur.

The devastating effect of WNS on North American bat populations have been unprecedented. Mortality rates attributed to



Citation: White-nose syndrome occurrence map - by year (2019). Data Last Updated: 8/30/2019. Available at: https://www.whitenosesyndrome.org/static-page/wns-spread-maps.

Figure 2: WNS occurrence in North America, https://www.whitenosesyndrome.org/where-is-wns

WNS have reached up to 90 and 100% at hibernacula (Kunz and Tuttle 2009) causing the death of between 5.7 to 6.7 million bats in North America since it was first documented in New York during the winter of 2006/2007 (USFWS 2012). By the spring of 2020, WNS had been confirmed in bats in 35 states and seven Canadian provinces, and *Pd* confirmed in four additional states (Figure 2; USFWS 2020). Recent studies report that *Pd* found in Washington state is genetically similar to strains in the eastern US, suggesting it did not spread from Eurasia but instead from eastern North America (Lorch et al. 2016). Though it is unclear how *Pd* reached Washington, this is an example of how dramatically WNS can spread.

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).

Among bat species currently confirmed to be affected by WNS in other states, five occur in South Carolina. These species are all colonial cavity roosting bats, mainly from the *Myotis* genus. They include the big brown bat, eastern small-footed bat, little brown bat, northern long-eared bat, and tricolored bat. Two of the species currently confirmed to be affected by WNS elsewhere have been confirmed with the disease in South Carolina thus far. WNS was first confirmed in South Carolina in Pickens County on a tricolored bat (*Perimyotis subflavus*) in March of 2013.

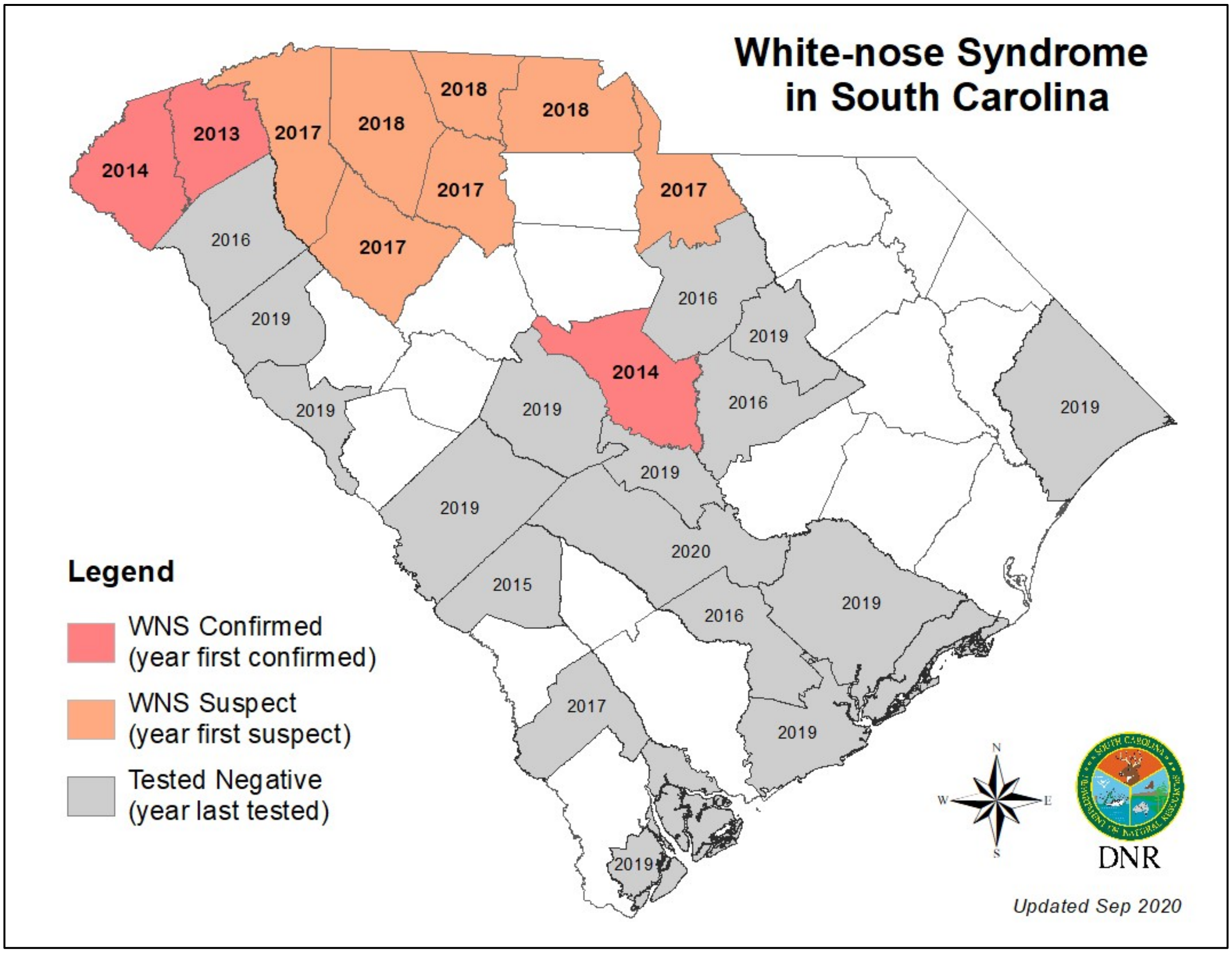


Figure 3: WNS occurence in South Carolina. While dark gray counties had *Pd* negative results, not all potential sites within those counties have been tested. Also, the lack of a positive *Pd* result does not definitively indicate the absence of the organism.

Since then, another case in Pickens county on an eastern small-footed bat (*Myotis lebii*) and two other cases in Oconee and Richland counties on tricolored bats have been reported in 2013 and 2014. Also during 2015, dead tricolored bats were found at the main Stumphouse Tunnel, one of which was tested and confirmed to have WNS. Overall, ten counties in South Carolina are either confirmed (Oconee, Pickens, Richland counties) or suspect for WNS (Cherokee, Greenville, Lancaster, Laurens, Spartanburg, Union, and York). WNS confirmed counties are those where the fungus is present and live or dead bats there have shown signs of being infected by the disease, such as wing damage and fungus growth on the muzzle and/or wings. WNS suspect counties are those where the fungus is present, but no clinical signs of the disease were observed on the bats. In 2017, Greenville, Lancaster, Laurens and Union counties and in 2018, Cherokee, Spartanburg, and York counties were added to the WNS spread map (Figure 3). Three counties (2 in the Piedmont, 1 in the Coastal Plain) were tested in 2019, but results came back negative for *Pd*. In 2020, Orangeburg was tested and results came back negative for *Pd*.

Pd has been detected on additional bat species in other states, but have not yet shown diagnostic signs of the disease. These species known to be present in South Carolina include two colonial cavity bat species, the Rafinesque's big-eared bat and Brazilian free-tailed bat, and two species that generally roost in foliage, the eastern red bat and silver-haired bat. The fungus was found on these bats while roosting in caves.

Significant over-winter mortality caused by WNS has been seen in little brown bat, northern long-eared bat and tricolored bat populations (Turner et al. 2011). WNS 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). The core region where much of the global population of little brown bats occur is now infected with WNS, and threatens to push these populations to extinction by 2026 (Frick et al. 2010*a*, Kunz and Reichard 2010). Across large portions of the eastern small-footed bats' range in New York, Massachusetts, and Vermont, populations declined 78% overall between 2006 and 2009 due to this disease (Langwig et al. 2009). 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. Northern long-eared bats are particularly vulnerable to WNS threats due to life history traits that make them slow to recover, such as low fecundity (Caceres and Pybus 1997, Caceres and Barclay 2000). According to Alves et al. (2014), an expected relative population reduction for eastern small-footed bats and northern long-eared bats is estimated to be 71.2% and 31.3% in intermediate population-reduction scenarios, 96.6% and 42.4% in pessimistic scenarios, and 29.3% and 12.9% in optimistic scenarios, respectively. Interestingly, the big brown bat seems highly resistant to WNS, limiting the degree of infection by *Pd* to the outer epidermis during torpor (Frank et al. 2014).

The common thread between species affected by WNS is that they're colonial cavity roosting bats that hibernate in cold, humid environments. This predisposes them to infection by *Pd* because the fungus survives in darkness in very similar temperatures from 36 to 57°F (2 to 14°C), (though it thrives in 55 to 60°F, or 12.5 to 15.8°C) and humidity of >90%; and the fact that bats suppress their immune system while in torpor during hibernation (Blehert et al. 2009, Verant et al. 2012, Lorch et al. 2013). According to Hayman et al. (2016), three species that are less severely impacted by WNS select drier areas within their hibernacula (Indiana, eastern small-footed, and big brown bats), while the three species most impacted by WNS select the most humid areas within their hibernacula (little brown, northern long-eared, and tri-colored bats). Also, the rapid spread of the fungus across eastern North America is likely due to the fact that many of these bats hibernate in clusters and healthy bats can readily come in contact with infected bats (Langwig et al. 2012). Additionally, the spores of *Pd* persist in caves year round and may be spread by humans on gear and clothing (Okoniewski et al. 2010), as well as by other bats and animals.

While there is promising research showing that bacteria native to North American soils (Cornelison et al. 2014) and bacteria from the skin of bats (Hoyt et al. 2015) can inhibit the growth of *Pd*, there are currently no treatments available to reduce the spread of WNS.

To help reduce the spread of *Pd*, please see the most updated National White-nose Syndrome Decontamination Protocol at https://www.whitenosesyndrome.org/. The most updated South Carolina White-nose Syndrome Response Plan can be found at http://www.dnr.sc.gov/wildlife/bats/batswns.html.

Habitat Loss and Alteration

Urbanization

South Carolina has one of the fastest growing populations in the U.S. (Strom Thurmond Institute 1998). Growing from less than 2.5 million in 1960 to over four million in 2000, it's expected to reach over five million by 2030 (SCFC 2010). Much of this growth results in the conversion of forestland to residential areas in the form of urban sprawl (Macie and Hermansen 2002, Slade 2008).

Urbanization has been cited as the leading threat to southern forests, and Wear and Greis (2011) anticipate a minimum 7% forest loss over the next 50 years. In addition to this is the decrease in the functional value of forests through increased fragmentation, reduced water quality, reduced carbon storage, and increased complexity in the use of fire for forest management practices. According to the South Carolina Forestry Commission (2010), much of urbanized land being converted from highly productive forest land no longer provides water quality protection, and is now uninhabitable to most wildlife species. For example, expanding urbanization is one of the major factors contributing to the loss of bottomland hardwood forest critical to bat species in the southeast (Smith et al. 2009, Loeb et al. 2011). Also, residential development and citrus grove plantations may threaten northern yellow bats if they result in the loss of sandhill and oak hammock habitats (Humphrey 1992). Lastly, the threat of wildfires increases with the increasing human population (SCFC 2010), and blue jays (*Cyanocitta cristata*) in suburban areas may be a potential threat to species such as hoary bats (Bolster 2005).

Though there are programs seeking to mitigate these negative effects and promote healthy urban forests, such as the South Carolina Forestry Commission's Urban & Community Forestry Program, productive forest land habitat needed by bats is often lost through urbanization. In addition, many forms of habitat alteration may inadvertently increase predation by natural predators and unnatural predators such as feral cats.

Agricultural Land Use

Historically, the primary cause of deforestation in South Carolina was due to the conversion of land for agricultural purposes. In the Southeast, 80% of bottomland hardwood forests were converted for agriculture purposes from the time of European settlement until around 1970 (Wear and Greis 2002). However, between 1968 and 2006, South Carolina's agricultural land decreased by 60% or two million acres (SCFC 2010). Today, South Carolina has approximately 4.9 million acres of farmland, or 25.8% of the state's land area (London 2015). The market value (total cash receipts) of agricultural products sold in 2012 totaled over $2.9 billion and the top five agricultural commodities were: 1) poultry (broilers), 2) turkeys, 3) greenhouse/nursery, 4) cotton, and 5) corn (United States Department of Agriculture Economic Research Service 2015).

Conversion of land to agricultural production has been one of the major factors contributing to the loss of bottomland hardwood forest (Smith et al. 2009, Loeb et al. 2011). However, since agricultural lands are now being converted into either urban uses or forest land, loss of habitat from the conversion of forest for agricultural purposes is not a primary concern compared to other threats. Instead however, agrochemicals may negatively impact bat prey availability in existing agricultural areas. A study by Wickramasinghe et al. (2004) found there was a significant increase in insect abundance, species richness, and moth species diversity on organic farms that used no agrochemicals compared to conventional farms, and that five insect families were significantly more abundant on organic farms. No research has been conducted to assess the impacts of agriculture on bats in South Carolina, but in 2011, only 802 acres of the 4.9 million acres of farmland in the state were organic (United States Department of Agriculture Economic Research Service 2015).

Hydrological Alteration

In the past, habitats such as bottomland hardwood forests relied on natural cyclic-flooding events to thrive. Natural riparian areas provided high water quality and benthic habitat in the form of coarse woody debris for insect larvae, prevented sedimentation collection, and provided cooler temperatures from the shade of trees (Gilliam 1994, Broadmeadow and Nisbet 2004, Anbumozhi et al. 2005). Carolina bays also provided various wetland functions such as nutrient cycling and biodiversity conservation (Bennett and Nelson 1991, Sharitz and Gresham 1998).

Disturbance patterns occurring naturally are complicated and influenced by a multitude of variables (King and Antrobus 2001), and the affects of human-made hydrological alterations on these natural processes can have unfavorable and unplanned results on bat habitat through change in forest composition and structure. For example, extensive flooding caused or exacerbated by anthropological land use changes can lead to significant stress on forest productivity (Megonigal et al. 1997) or direct mortality such as in the death of 57,000 bats in Florida (Gore and Hovis 1994). In addition, ditches, channels and impoundments can change water temperature as well as facilitate high sediment loads into wetlands, which affects ecosystem richness and productivity by covering aquatic vegetation, increasing turbidity, and reducing oxygen content. Impoundments also decrease water circulation, preventing outflow of nutrients, changing dissolved oxygen and pH levels, and increasing the accumulation of toxic substances in sediments (US Environmental Protection Agency 1993).

Altered hydrology can also cause habitat fragmentation, which is associated with numerous negative impacts to wildlife (Harris 1988, Fleming et al. 1994). Approximately 97% of Carolina bays have been disturbed in South Carolina (Bennett and Nelson 1991, Sharitz and Gresham 1998), and fragmented bottomland hardwood forests may have a reduced capacity to store flood water, trap nutrients, recharge groundwater, and provide wildlife habitat (Mississippi Museum of Natural Science 2005). Alteration of natural flood regimes may also affect the regeneration of important forest community types such as cypress-gum, thus preventing recruitment of future roost trees (Bunch et al. 2015*b*). Altered hydrological regimes could also cause the outright loss of cypress and tupelo gum swamps, bottomland hardwood, and other forested wetlands, and the loss of these habitats are known to contribute to the decline of bat species (Mirowsky and Horner 1997).

Forest Management

Forestry is the leading manufacturing industry in South Carolina when it comes to employment and labor income, and timber is the number one harvested crop. South Carolina has approximately 13.1 million acres of forest, occupying 68% of the state's land area. Of South Carolina's forests, 53% (6.9 million acres) are characterized as hardwood forest and 47% (6.2 million acres) as softwood (SCFC 2014).

The majority (88%) of South Carolina's forest is privately owned, with individual ownership at 58%, corporate ownership at 24%, and forest industry at 6% (Figure 4). Only 12% is owned by public agencies, and includes national forests at 5%, state, county and municipal lands at 4%, and other federal land at 3% (SCFC 2010, Conner 2011).

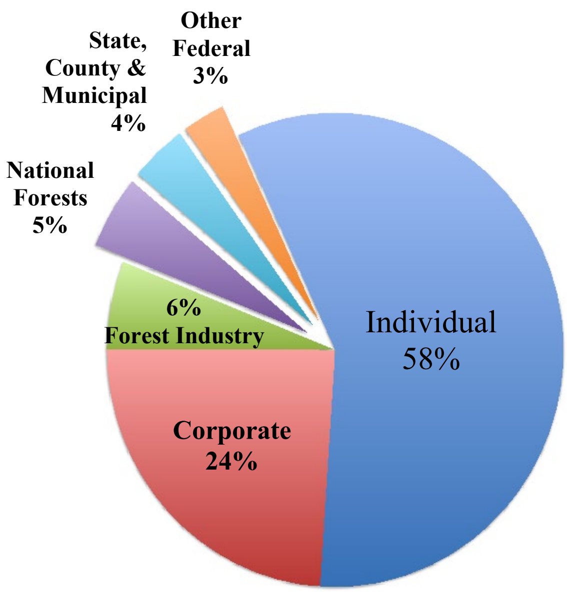


Figure 4: Forest land ownership in South Carolina (SCFC 2010, Conner 2011).

Forest industry has declined markedly in the past decade, and between 2001 and 2012 it was reduced by 88%. This decline continues today as forest land is transferred to private individuals and non-forest industry corporations. Because 11 million of the 13 million acres of forest are privately owned, this land is at risk for development. About one-fifth of these private individuals considered timber products from their land an important management objective, but there is concern that these forests will become increasingly parceled into smaller holdings, fragmented, and/or converted to non-forest uses (SCFC 2010).

Forests in the South have been fragmented and reduced in functionality and extent from various causes including timber harvesting practices (Noss et al. 1995, Wear and Greis 2002). Forest management has direct and indirect impacts on bats since these species have a close association with forest structure and vegetation (Guldin and Emmingham 2007). The felling of trees and snags, building of roads, disruption of boulders in quarries, prescribed burns, and vegetation and insect control are all forestry practices that can result in direct mortality of bats (Hayes and Loeb 2007). Indirect impacts from forest management have the potential to be greater and make lasting affects on bat populations due to their cascading nature. For example, the removal of mature, large-diameter trees and snags through commercial timber operations in the southeastern US (Gooding and Langford 2004, Wilson et al. 2007) reduces important roost availability for many bat species since tree size and stand age are important indicators of cavity abundance (Allen and Corn 1990, Fan et al. 2003, Barclay and Kurta 2007). The loss of existing snags and curtailed development of large snags from forestry practices means less maternity and roosting sites for silver-haired bats (Campbell et al. 1996, Mattson et al. 1996, Betts 1998). Additionally, loss and degradation of bottomland hardwood forest habitat through clearing and drainage along with the disappearance of extra large tree hollows has likely been a contributing factor in the vulnerability of Rafinesque's big-eared bats (Tiner 1984, Clark 2000, Mitsch and Gosselink 2001). Even if roosts aren't directly affected, forest fragmentation around roosts may increase the distance bats have to fly in order to find suitable foraging and drinking areas, and can lead to long-term declines in bat colony sizes (Clark 1990, Hurst and Lacki 1999, Adams and Hayes 2008). Forest management activities such as thinning effect the amount of vegetative clutter and tree density in a forest, which are factors strongly related to bat activity and can actually have a positive impact on certain species (Hayes and Loeb 2007). Additionally, because riparian zones are important to bats, providing a riparian zone buffer during timber harvests would help minimize the impact to bats. The functional width of riparian buffer zones near small streams, according to a study by O'Keefe et al. (2013), is greater than or equal to 32 feet (10 m). However, research on larger buffer zone sizes still needs to be conducted.

Currently, South Carolina has more forest land and timber volume than ever recorded. However, due to the creation of large portions of young forest in a short period of time through the Conservation Reserve Program and Hurricane Hugo reforestation efforts, much of these tree stands are of similar age (SCFC 2010). This lack of age and size class diversity does not provide as wide an array of habitat for bats as a similar area with more diversity might. Studies show that monotypic stands don't provide quality foraging areas for bats, as the abundance of moth prey is reduced and foraging success is lowered (Summerville and Crist 2002, Lacki and Dodd 2011). For example, even-age timber management practices could have an adverse affect on the threatened northern long-eared bat because mature forest stands are important habitat to this species (Caceres and Pybus 1997). Destruction and fragmentation of mature forests in the mountains and Coastal Plain of South Carolina is also a major threat to Rafinesque's big-eared bats and southeastern bats because they depend on these areas for foraging and roosting (Bunch et al. 2015*b*).

Additionally, forestry management practices using a shorter rotation with altered composition of tree species can eventually create a less complex, relatively uniform overstory and a denser understory (Guldin and Emmingham 2007). Management that allows for variation in tree densities (Patriquin and Barclay 2003) as well as a diverse array of herbaceous and woody plants could play a positive role in bat species richness by providing important habitat necessary for the development of prey species consumed by bats such as Rafinesque's big-eared bats (Dodd et al. 2008, Lacki and Dodd 2011). Forestry practices may also impact some of the most sensitive natural habitats in the state such as caves, sinkholes, and springs (SCFC 2010). These environments are important areas for bats as they provide hibernacula and, especially during periods of drought, key water resources.

Prescribed fire during cold weather may also pose a threat as eastern red bats (Mager and Nelson 2001) and other lasiurine bats are known to use leaf litter during hibernation (Moorman et al. 1999, Rodrique et al. 2001, Hein et al. 2005, Mormann and Robbins 2007). If prescribed burns are conducted during colder winter periods (e.g < 60°F (15°C)), bats roosting beneath leaf litter may be in deep torpor and less likely to escape approaching flames then during warmer periods when they are in shallow torpor (Perry and McDaniel 2015). Increased wind speed during prescribed fires has been found to decrease latencies of response behavior in torpid red bats, as smoke propelled by wind greatly increases bat awareness (Layne 2009).

Loss of Anthropogenic Roosting Habitat

Anthropogenic structures such as mines, wells, cisterns, buildings, and bridges can provide habitat for many species of South Carolina's bats. However, when these structures are closed, filled in, taken down, or renovated to newer designs, bats may lose important roosting or maternity sites (Clark 1990, Keeley and Tuttle 1999, Sherwin et al. 2009). Mine closures can make a significant impact as destruction of hibernacula is the main factor in population declines of bat species dependent on caves and mines (Humphrey 1978, Sheffield and Chapman 1992). The direct impact of mine closures cause bat mortality if they occur during hibernation. Indirect impacts during non-hibernating periods may force bats such as the federally threatened northern long-eared bat to burn critical fat reserves while searching for new hibernacula (USFWS 2011). Also, human-made structures that more recently took the place of tree hollows as colonial roosts are being lost in some areas of the southeast (Clark 1990, Belwood 1992, Lance 1999).

Loss of Spanish Moss and Palm Fronds

The loss of Spanish moss due to a fungal infection poses a big threat to the roosting habitat of northern yellow bats and Seminole bats. Loss due to fungal infection is a possibility due to an outbreak during the 1960's that caused Spanish moss to be eliminated from many areas of central Florida (Smith and Wood 1975, Jensen 1982). The harvesting of Spanish moss may be a problem for these bat species in some areas. However, the development of synthetic materials replacing the need for Spanish moss may have reduced this threat (Trani et al. 2007). Habitat and roost site loss due to the removal of palm fronds is another potential issue for northern yellow bats, evening bats, and Seminole bats (Mirowsky 1997, Bunch et al. 2015*c*).

Sudden Oak Death

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*).

Feral Hogs

Feral hogs can negatively alter bat habitat by influencing future overstory composition, reducing tree diversity, decreasing plant cover and surface litter, and changing soil composition and chemistry (Siemann et al. 2009). Hogs could also potentially forage on bats roosting in the leaf litter.

Human Disturbance

Disturbance and vandalism of hibernacula by human activities poses a major threat for hibernating bat species (Tuttle 1979, Thomas et al. 1990, Caceres and Pybus 1997). Along with disturbance during summer maternity periods, these threats are a significant factor in the widespread decline of species dependent on caves and mines (Humphrey 1975, Sheffield and Chapman 1992, Amelon and Burhans 2006*a*). There are numerous reports of roosting and nursery colony abandonment due to excessive disturbance, banding and radiotelemetry studies, and survey and netting operations (Watkins 1969, Bain 1981, Clem 1992). Other examples of human disturbance that have lead to abandonment 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). Mass die-offs of little brown bats at hibernacula not related to WNS have been associated with vandalism (Gould 1970).

Disturbance to hibernacula causes bats to deplete their fat supplies and abandon caves, such as with the threatened northern long-eared bat (Caceres and Pybus 1997). The loss of energy stores may affect overwinter viability as well as other life history events, such as the lowering of reproductive rates due to bats being significantly smaller during the reproductive period (Reichard and Kunz

2009). 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).

Climate Change

Global climate change is a potential threat to bat species due to the predicted rise in regional temperatures (IPCC 2012). Bats depend highly on temperature for important life history processes such as hibernation, reproduction, and growth, so a change in climate could potentially cause earlier hibernation emergence, extended foraging seasons, and earlier birth of young (Jones et al. 2009).

Bat habitat is also threatened through drought and heat stress associated with climate change (Hanson and Weltzin 2000, Rennenberg et al. 2006, Allen et al. 2010), which has the potential to cause increased tree mortality, insect outbreaks and wildfire. Additionally, roost sites may change as the shift in temperature and precipitation patterns predicted by various climate models alters vegetation (Prentice et al. 1991, Ayres 1993). These changes may make habitat unsuitable and ultimately modify bat distribution through the shifting of their range, as it has with wildlife in other areas (Pörtner and Farrell 2008, Loarie et al. 2009, Loeb and Winters 2013). Migratory bats may also be negatively affected by habitat degradation from climate change (Robinson et al. 2009). Continued change in temperature and precipitation may also alter the availability of insectivorous prey (Bale et al. 2002, Robinson et al. 2009). Climate change has been documented as negatively affecting songbird populations in this way (Strode 2003, Both and Visser 2005).

Though some climate models predict an increase in violent weather events that could affect bat populations in fragmented habitats, the Intergovernmental Panel on Climate Change (IPCC) report on extreme weather events states a lack of strong evidence to support this (IPCC 2012).

Specifically for hibernating bats in South Carolina, the temperature at southern hibernation sites may become too warm and/or fluctuate too greatly. This threat has the potential to cause bats such as the eastern small-footed bat to deplete energy reserves through more frequent arousal from torpor since it hibernates in areas more susceptible to fluctuations in temperature (Humphries et al. 2002, Rodenhouse et al. 2009). However, the exact role that climate change will play in the state on bats and their habitat is largely unknown due to climate model limitations and inadequate experimental data. But if prolonged drought conditions occur, the recruitment of tree species specific to wetlands and bottomland hardwoods would be impacted, and those lands may also become more susceptible to conversion and development (BCI and SBDN 2013).

Wind Energy Development

Wind turbine facilities are a threat to many bats as an estimated 450,000 bat fatalities occur at these locations annually in North America (Ellison 2012). This threat can come from direct mortality caused by either blade strikes or through barotrauma where a sudden change in air pressure near the blades causes damage to lung tissues of bats (Kunz et al. 2007, Baerwald et al. 2008). In addition, habitat loss and fragmentation is associated with construction of these facilities (Arnett et al. 2007). Wind turbine facilities in North America have been increasing in recent years and are expected to continue as the demand for energy increases and fossil fuels become less popular due to sustainability issues, environmental impacts, and wildlife concerns

(Inkley et al. 2004, Kuvlesky et al. 2007, Arnett et al. 2008). 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, Arnett et al. 2008), and that facilities built on ridge tops appear to have the highest bat fatalities (Johnson and Erickson 2008). In fact, many of the highest mortalities reported come from wind energy sites on forested ridges in the eastern US at 15 to 41 bats killed per megawatt per year (Kunz et al. 2007). Also, estimates of mortality from wind turbines are likely underestimated due to the challenge in finding all carcasses, and the impact from these fatalities may have a cumulative effect on bat populations due to their low reproductive rates.

The majority of wind turbine related deaths is composed of migratory bat species such as eastern red bats, hoary bats, and silver-haired bats, especially during later summer and early fall (Ellison 2012). Hoary bat fatalities are the most prevalent and compose about half of the 450,000 annual bat fatalities at wind facilities in North America, while silver-haired bat mortalities compose about one-fifth of that estimate (Cryan 2011, Ellison 2012). Eastern red bats are also often one of the top species recorded with the most bat fatalities (Ellison 2012). Fiedler (2004) found that 61.3% of the bat fatalities at a wind farm in eastern Tennessee were eastern red bats. The reason wind energy poses a larger risk to migratory bats is likely due to seasonality and migration patterns that make them more vulnerable to collisions (Cryan 2011), such as the use of ridge tops by bats during migration (Johnson and Erickson 2008).

Though the percentages of direct fatalities are low compared to migratory tree bats, wind energy also threatens other species found in South Carolina including tricolored bats, Brazilian free-tailed bats, northern long-eared bats, small-footed bats, little brown bats, and big brown bats. 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). Piorkowski and O'Connell (2010) showed a steady rate of collision mortality of Brazilian free-tailed bats 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. Wind energy development also threatens northern long-eared bats through direct mortality and the clearing of mature forests for turbines and road construction (Kerns and Kerlinger 2004, Johnson 2005). Because the eastern small-footed bat tends to roost in talus areas occurring on ridge tops, wind power development may adversely affect this species through habitat loss from construction as well (Amelon and Burhans 2006*b*). Little brown bats and big brown bats comprise a small percentage of total fatalities at wind energy developments in the US compared to other species, with little brown bats comprising 5.9% and big brown bats only 1.9% (Johnson 2005). No reports of southeastern bat mortalities by wind turbines have yet been reported, but since other *Myotis* species have been affected, this species may be vulnerable if wind facilities are built near their colonies. The effects of potential off-shore wind farms on bats such as the northern yellow bat are unknown.

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*). Also, areas of the southeast have ideal wind development areas including high-elevation mountain tops, plains, and coastal areas, and Federal Aviation Administration databases indicate numerous proposals for wind energy development across the southeast (BCI and SBDN 2013). It is possible to reduce bat mortality from wind energy by feathering turbine blades (turning them parallel to the wind, affectively idling them) and increasing the cut-in speed. In a synthesis of studies on reducing bat fatalities at wing energy facilities, Arnett et al. (2013) reported that when turbine cut-in speed was increased between 1.5 and 3.0 m/s there was at least a 50% reduction in bat fatalities, and that feathering resulted in up to 72% less bat mortality when turbines produced no electricity for the power grid. In fact, 17 members of the American Wind Energy Association have recently recognized this and volunteered to idle turbines at low wind speeds during peak migration season, potentially reducing bat fatalities at wind farms by 30% (Curry 2015).

Environmental Contaminants

There is increasing evidence that a considerable factor in the decline of bats is exposure to environmental contaminants (Gerell and Lundberg 1993, Clark 2001, Hickey et al. 2001). Pesticide poisoning, especially by organochlorines and anticholinestrase, has been shown to cause population declines in insectivorous bats (Geluso et al. 1976, Reidinger 1976, Brady et al. 1982). Pesticides on forested public lands can cause mortality to both bats and their prey (Bolster 2005). For example, when applied for control purposes they can cause direct mortality to little brown bats, or indirect mortality through their insect prey (Kunz et al. 1977). Pesticides can also alter bat behavior and be transferred to nursing young (Clark 1981, 1986, Henny et al. 1982). Additionally, bats may suffer a delayed affect when high levels are released from stored fat deposits metabolized during weaning, migration, or at the end of hibernation (Geluso et al. 1976, Bennett and Monte 2007). Bat species that consume large amounts of crop pests may have an increased risk of contamination from the accumulation of organochlorine pesticides in body fat. For example, population declines of the Brazilian free-tailed bat reported over the last 50 to 100 years in the US may partially be due to direct or indirect poisoning by pesticides and heavy metals (McCracken 1986, Gannon et al. 2005). Rafinesque's big-eared bat may also be vulnerable to pesticides given the reliance this species has on moths (Hurst and Lacki 1999, Lacki and LaDeur 2001). 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 Rafinesque's big-eared bats (Bunch et al. 2015*b*).

Contaminants of emerging concern, such as flame retardants, pharmaceuticals and personal care products, have been discovered in high concentrations in bats. A recent study by Secord et al. (2015) found that out of 48 bat carcasses collected in the northeastern US, 100% showed high detection frequencies of polybrominated diphenyl ethers (PBDEs), or flame retardants, in their system. Also in relatively high detection frequencies were salicylic acid (81%), thiabendazole (50%), caffeine (23%), and in at least 15% were compounds such as ibuprofen, penicillin V, testosterone, and DEET. Though it is not known how these chemicals affect bats, it is possible that they could make them more susceptible to WNS, or in the case of caffeine, arouse bats out of hibernation prematurely.

Elevated levels of contaminants such as heavy metals like mercury have been found in bats, and can be toxic in high concentrations. In a South Carolina study on Rafinesque's big-eared bats, Bennett et al. (2003) found elevated levels of Al, Cd, Cr, Cu, Hg, Ni, Pb, and Zn in all hair samples measured, and As and Se in the majority of samples. The Al (aluminum) concentrations in hair samples were an order of magnitude higher than those found in little brown bats in Ontario and Quebec. Other concerning results were the levels of Pb (lead) and Hg (mercury), which are considered highly toxic to wildlife. Of the samples measured, 24 % had an amount of lead greater than the lower limit considered toxic. Even worse, 55% of the samples had mercury near or above the level at which detrimental effects have been recorded in humans and rodents. Many bats, such as the silver-haired bat, may be particularly vulnerable to heavy metal contamination due to their tendency to forage over water. Eastern small-footed bats may also be particularly vulnerable to environmental contaminants due to their small body size and association with mining activities (Amelon and Burhans 2006*b*). Waterways in South Carolina with mercury and PCB advisories can be seen at http://www.scdhec.gov/FoodSafety/Docs/FISH2015.pdf

Other Threats

Inadequacy of Existing Regulations

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

Collisions from Buildings

Large buildings also pose a collision threat to some migratory species such as eastern red bats (Timm 1989). Additionally, small numbers of deadly collisions with towers in Florida have been recorded for Seminole and southeastern bats (Crawford and Baker 1981). In South Carolina, the carcass of a hoary bat that hit a power line exists at the Campbell Museum of Natural History. However, the level of impact from tower or building mortalities on local or range-wide populations is a relatively minor threat.

Current Conservation, Management, and Outreach Activities

Surveys and Research

Past and Current Surveys and Research

One of the earliest comprehensive reports on the species, distribution and natural history of 11 of the 14 bats in South Carolina was provided in a general mammal survey of the state by Golley (1966). That information was updated by Neuhauser and DiSalvo (1972) with the first record of a southeastern bat in the state, new county records for other bats, and expanded ranges for Seminole and Brazilian free-tailed bats. Using bats submitted for rabies testing, DiSalvo et al. (2002) further updated these bat species distributions. One year later J. M. Menzel et al. (2003) contributed additional information to the South Carolina bat distribution maps from museum records, captures reported in literature, and records maintained by SCDNR.

Most research specifically investigating natural history of South Carolina bats did not begin until the late 1980's. Results from these early bat surveys exist in internal documents but are reflected in the Campbell Museum of Natural History records at Clemson University. Available studies from the late 1990's ranging from topics on diet, roosting habits, foraging habits, and species prelisting recovery come in the form of survey reports (Cothran et al. 1991, Bunch et al. 1997, 1998*a*, *b*, Bunch 1998, Bunch and Dye 1999*a*, *b*, Louie et al. 2001), unpublished master's theses (Carter 1998, Menzel 1998), and an honors project (Donahue 1998).

Between 2000 and 2003, a large portion of bat research was conducted in the Sandhill ecoregion at the U.S. Department of Energy's Savannah River Site on 12 of the 14 bat species of South Carolina (Menzel et al. 2000*a*, 2001*c*, 2002*d*, *b*, M. A. Menzel et al. 2003). These studies focused on foraging ecology, tree roost selection, home range, habitat use, diet, and spatial activity patterns. Since 2003, research studies on specific bat species and communities in various regions of the state have been conducted on bat activity (Menzel et al. 2005*b*, Hein 2008, Loeb and Waldrop 2008, Moore 2015), community and social structure (Loeb et al. 2009, Loeb and Britzke 2010), diet (Armbruster 2003, Carter et al. 2004), presence and absence (Ford et al. 2006*a*), habitat use (Loeb and O'Keefe 2006), roost site selection (Leput 2004, Hein et al. 2005, 2008*a*, Bennett et al. 2008, Loeb and Zarnoch 2011), variation in metal concentrations (Bennett 2004), and the presence or absence of rare, threatened, and endangered species (Webster 2013). Current studies include research lead by Susan Loeb on foraging and roosting habitat of southeastern bats at Congaree National Park and an ongoing study on band injury rates of big brown bats. Results from the master's thesis of Ben Neece, analyzing echolocation calls collected in SC through the North American Bat Monitoring Program, should become available in late 2017.

South Carolina bat surveys are generally conducted by SCDNR and the USFS. SCDNR has conducted multiple surveys at the Army National Guard's McCrady Training Center (previously known as the Leesburg Training Site) in the Sandhills ecoregion of the state (Bunch et al. 1997, 1998*b*) and the Naval Facilities Engineering Command in the Coastal Zone ecoregion (Bunch 1998, Louie et al. 2001). Winter hibernacula counts in the Blueridge and Piedmont ecoregions are the largest ongoing surveys and are conducted on a three to five year rotation by SCDNR. The USFS Southern Research Station has been conducting annual winter counts at the Clemson University owned railroad tunnel for the past three years.

The most information collected on a single species in South Carolina thus far has been on Rafinesque's big-eared bat. This is probably due to its long standing status as state endangered, and the fact that relative abundance and distribution of the species are not easily estimated due to capture and detection challenges.

The North American Bat Monitoring Program (NABat) (Loeb et al. 2015), a nation-wide, long-term acoustic monitoring effort was started and run in South Carolina from 2015-2016 by master's student Ben Neece and Dr. Susan Loeb from Clemson University. SCDNR partnered with the university as well as USFS Southern Research Station, USFWS, and others to help initiate the program in SC. Standardized acoustic sampling of bat calls are surveyed using 38, 10 X 10 km cells generated randomly across the state by the USGS. Stationary site and mobile route surveys are conducted annually from May to July, and the effort for these surveys depend heavily on volunteers and state and federal organizations across the state. SCDNR ran the program in the summer of 2017, and hopes to do so into the future.

Habitat and Species Protection

Lands protected in South Carolina by federal, state, or nonprofit conservation organizations conserve a total of 11% of the state. Overall conservation acreages in the state include 469,000 (190,000 ha) for state-owned, 990,000 (400,000 ha) for federally owned, 671,000 (272,000 ha) for privately owned, and 91,000 (37,000 ha) for military owned lands (SCDNR 2015). The Blue Ridge ecoregion has the greatest percentage of land conserved at 57%, where approximately 163,000 acres (66,000 ha) are protected by preserves, conservation easements, and national forests such as Ashmore Heritage Preserve, the South Saluda watershed of the Greenville Water System, the Andrew Pickens District of Sumter National Forest, and the Mountain Bridge Wilderness Area (Bunch et al. 2015*b*). For the other ecoregions, 29% of the Coastal Zone, 14% of the Sandhills, 10% of the Coastal Plain, and 6% of the Piedmont at 6% are protected (SCDNR 2015). In terms of the largest number of acres protected, the Coastal Plain is responsible for 39% of South Carolina's conserved land, with federal lands and public ownership playing major role in habitat protection. In this ecoregion, Congaree National Park encompasses nearly 27,000 acres (10,926 ha) and is the largest old growth bottomland hardwood forest in the southeastern US. Also, Francis Beidler Forest, owned by the Audubon Society, protects 16,000 (6,475 ha) acres of old-growth swamp.

As mentioned in the Legal and Conservation Status section of this document, bat species are protected on Heritage Preserves and SCDNR owned lands (CL 50-11-2200 (C), Appendix A). The Heritage Trust Program protects critical natural habitats and significant cultural sites in heritage preserves, and identifies conservation ranks for South Carolina bat species according to NatureServe criteria (Table 2). The Heritage Trust Program also maintains a database with current and historical bat data that's been collected in the state. Other SCDNR habitat protection programs include the Forest Legacy Program, Focus Area Program, ACE Basin Project, Scenic Rivers Program, South Carolina Conservation Bank Act, National Estuarine Research Reserve System, South Carolina Land Trust Network, and Beach Sweep/River Sweep (SCDNR 2015).

Conservation Plans and Recommendations

The South Carolina SWAP identifies 12 of the 14 bats in the state as species of conservation concern or greatest conservation need (Table 2) (SCDNR 2015). Conservation recommendations for these species are provided in the Supplemental Volumes of the plan and titled Colonial Cavity Roosting Bats Guild, the Foliage Roosting Bats Guild, and Silver-haired Bat (Bunch et al. 2015*b*, *c*, *a*). These recommendations include specific information for management, priority research and survey needs, monitoring, education, public outreach and cooperative efforts in South Carolina.

"A Conservation Strategy for Rafinesque's Big-Eared Bat (*Corynorhinus rafinesquii*) and Southeastern Myotis (*Myotis austroriparius*)" (BCI and SBDN 2013) is an extremely detailed plan developed to help guide conservation and management of these South Carolina bat species. Also, the symposium on the "Conservation and Management of Eastern Big-eared Bats" (Loeb et al. 2011) is particularly useful for information regarding the conservation needs and management of Rafinesque's big-eared bats. The "Conservation Assessments for Five Forest Bat Species in the Eastern United States" consolidated and synthesized by the USFS (Thompson 2006) provides conservation information for the southeastern bat, eastern small-footed bat, northern long-eared bat, tricolored bat, and evening bat. In this document, potential threats, estimates of habitat availability, and percentages of protected habitat available within the National Forest System are outlined. Additionally, estimates of habitat availability are shown in the form of acreage across ownerships, such as federally owned, State-owned, county or municipal-owned, and privately-owned lands.

Educational Outreach

Current Informational and Bat Management Materials

Informational materials on South Carolina bats are largely provided by SCDNR. The department contributed to a major educational outreach tool, the "Bats of the Eastern United States" bat identification poster, which is provided for free to the public. Other materials can be accessed on the SCDNR website, and the following are descriptions and links to these documents.

SC bats in buildings - written specifically for the public, this document provides information on the bats of South Carolina, how to safely exclude them from structures and living quarters, and provides links on how to build bat boxes and report South Carolina bat colonies.
http://www.dnr.sc.gov/wildlife/publications/nuisance/SCbatsinbldgs.pdf

Bats and White Nose Syndrome (WNS) - this webpage describes WNS, why it's a problem, what SCDNR is doing about it, and what the public should do if a dead bat is found. It also provides links to the recently updated South Carolina WNS response plan, a document on the Bats of the Southern Appalachians, an informative USFS video, and additional information on WNS.
http://www.dnr.sc.gov/wildlife/bats/batswns.html

The South Carolina SWAP link provides the entire action plan for the state:
http://dnr.sc.gov/swap/index.html. Bat species information in the SWAP is found under the Supplemental Volume, Mammals section. For the Colonial Cavity Roosting Bats Guild:
http://dnr.sc.gov/swap/supplemental/mammals/colonialcavityroostingbatsguild2015.pdf
For the Foliage Roosting Bats Guild:
http://dnr.sc.gov/swap/supplemental/mammals/foliageroostingbatsguild2015.pdf
For the Silver-haired Bat:
http://dnr.sc.gov/swap/supplemental/mammals/silverhairedbat2015.pdf

The Rare, Threatened and Endangered Species Inventory link lists these species in South Carolina by county:
http://www.dnr.sc.gov/species/index.html

Bat Conservation Organizations

National and Regional Levels

A major player on the national level of bat conservation is Bat Conservation International (BCI), a non-governmental organization that works to conserve the world's bats and their ecosystems. In the US, they have conducted research and conservation activities to protect habitat, mitigate threats to bats, and educate the public. Specifically, they help safeguard critical bat colonies in Texas and Alabama, address the threat of wind energy and water scarcity for bats, and provide resources and funding toward WNS recovery efforts. On the regional level, the Southeastern Bat Diversity Network (SBDN) helps to conserve bats and their habitats as well as facilitate education, research, and management in the Southeast.

This working group is composed of bat biologists, land managers and others from 16 southeastern states seeking to facilitate communication, identify bat conservation priorities, and implement conservation programs regionally. Together, BCI and SBDN created the Conservation Strategy for Rafinesque's Big-Eared Bat (*Corynorhinus rafinesquii*) and Southeastern Myotis (*Myotis austroriparius*) (BCI and SBDN 2013)