STATUS REVIEW OF THE LITTLE BROWN MYOTIS (*MYOTIS LUCIFUGUS*) AND DETERMINATION THAT IMMEDIATE LISTING UNDER THE ENDANGERED SPECIES ACT IS SCIENTIFICALLY AND LEGALLY WARRANTED

*Healthy Little brown myotis in flight
Credit: M. Brock Fenton

*Little brown myotis carcasses in Aelous Cave, VT in 2009
Credit: Jonathan D. Reichard, Boston University's CECB

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I. EXECUTIVE SUMMARY

The little brown myotis (*Myotis lucifugus*) was once considered a common bat species because of its wide distribution, conspicuous maternity colonies, and relatively stable population status. However, emerging evidence recently published in one of the world's leading peer-reviewed scientific journals, *Science*, conclusively demonstrates that the species is in sharp decline due to the rapidly spreading white-nose syndrome (WNS) that has already resulted in several local extirpations and that is ultimately expected to cause regional and likely rangewide extinction of the little brown myotis in a very short ecological time frame (Frick et al. 2010b). Specifically, this paper projects that regional species extinction will likely occur, with 99% certainty, in or before 2026 (Frick et al. 2010b) – eliminating at least the core northeastern range of the species, which clearly constitutes a significant portion of the species' range in terms of population numbers, geographical distribution, resiliency, and habitat composition. The emerging science paints a grim picture of a once-healthy population being driven to extinction in a precipitous and unprecedented manner.

In light of the need for an immediate response to the WNS crisis, we have conducted this status review to analyze the best available scientific evidence regarding the continued viability of the little brown myotis in its core northeastern range and throughout its entire range in North America, in light of a continental-scale pandemic. Based on the study referenced above and other available data on WNS and its effects on the little brown myotis, we have concluded in this status review that extinction is virtually certain to occur in the core range of this species by 2026, and rangewide extinction may very well follow based on known and predicted infection dynamics of WNS.

Accordingly, this status review concludes, after applying the best available science to the legal and regulatory requirements of the Endangered Species Act ("ESA"), 16 U.S.C. §§ 1531-1544, that an endangered listing is warranted because the species is in imminent danger of extinction throughout a critical and significant portion of its range (the northeastern U.S), and is likely in danger of extinction throughout its entire range. *Id.* § 1533(a)(1). In addition, because of the immediacy and magnitude of the exigent WNS threat posed to the little brown myotis, this pandemic argues in favor of an emergency listing under the ESA while the U.S. Fish and Wildlife Service (FWS or Service) conducts its own species status assessment. *Id.* § 1533(b)(7).

II. NATURAL HISTORY AND ECOLOGY

A. Taxonomy

The little brown myotis is a member of the Mammalian order Chiroptera, family Vespertilionidae, genus and species *Myotis lucifugus* (LeConte 1831). Six subspecies have been recognized (Fenton and Barclay 1980), but overlapping ranges and hybridization have called into question these subspecific desinations (Laussen et al. 2008).

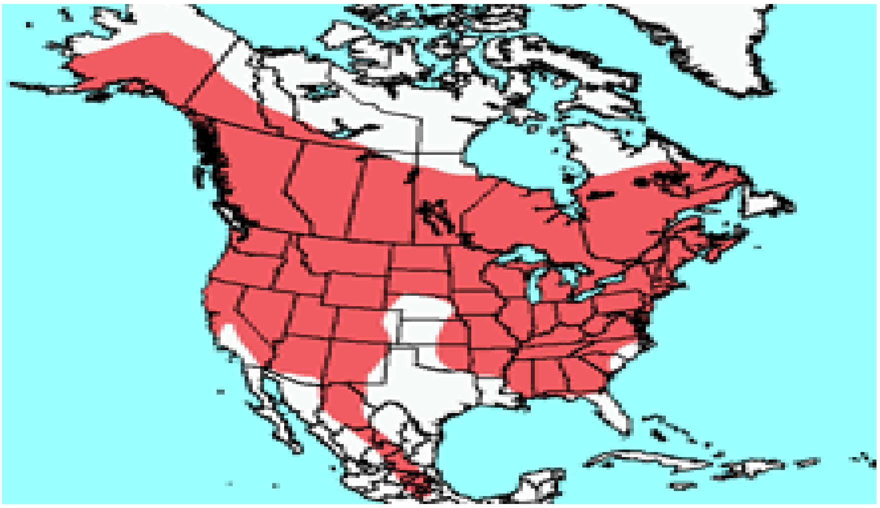
B. Description

The little brown myotis is a small North American bat with variable coloration ranging from pale to dark brown, which is often described as "dark sooty brown through paler golden" dorsally and "pallid, to yellowish or olive brown" ventrally (Fenton and Barclay 1980). Adult body mass ranges between 7 - 9 g (Kalcounis and Brigham 1995; Kunz et al. 1998) and can increase by 30% during pregnancy (Hughes and Rayner 1993; Kurta and Kunz 1987). Length of forearm ranges from ca. 31 - 41 mm and wingspan ca. 250 - 270 mm (Kalcounis and Brigham 1995). The length of the head and body is ca. 54 - 57 mm (Williams and Findley 1979) and length of the tail is ca. 36 - 42 mm (Kalcounis and Brigham 1995). The little brown myotis can be distinguished from similar sympatric species, such as the Indiana myotis (*M. sodalis*) and northern long-eared myotis (*M. septentrionalis*), by the length of ears and tragus, pelage length and sheen, lack of a keeled calcar, and ear color (Barbour and Davis 1969). Recordings of echolocation calls and genetic analysis have greatly increased accuracy of species identification (Rodhouse et al. 2008). Although sexes are similar in appearance, adult males are often smaller than adult females (Kalcounis and Brigham 1995).

First year survival of female little brown myotis ranges from 23-46% and is higher for young born earlier in the summer (Frick et al. 2010a). Adult survival rate was 63-90% from 1993-2008 (Frick et al. 2010a). The oldest recorded wild, free-ranging little brown myotis was 31 years when last captured (Fenton and Barclay 1980).

C. Geographic Distribution

As the map below depicts, in the early 1980's, the little brown myotis was geographically distributed across North America from Alaska to Nova Scotia in the north, and from northern Florida to central Mexico east of the Sierra Madre Occidental in the south (Fenton and Barclay 1980). Distribution is limited by the availability of suitable caves and mines for hibernation, temperatures inside hibernacula, and by the length of the hibernation season (Humphries et al. 2002; Humphries et al. 2006). Although no study has directly connected population density of little brown myotis to cave availability, it is believed that the high density of caves in the Appalachian Mountain range and eastern Midwest (Culver et al. 1999) support much larger populations of this species than in other parts in the species' range. The largest known colonies of little brown myotis are in the northeastern and mid-western United States, with the northeastern population considered the core range of the species.



* Geographic range of the little brown myotis. Source: Fenton and Barclay 1980.

D. Habitat

1. Winter Habitat/Hibernacula

In the late summer and fall, individual little brown myotis depart from summer roosts and migrate to a variety of transient roosts (Fenton and Barclay 1980) before arriving at winter hibernacula located up to 300 km from summer roosts (Davis and Hitchcock 1965; Fenton 1970; Griffin 1970; Humphrey and Cope 1976), or perhaps as far as 1,000 km (Wilson and Ruff 1999). Caves and mines serve as swarming sites during the autumn mating period and as hibernacula during the cold months. Swarming behavior in little brown myotis occurs from August through early October, which also coincides with the pre-hibernation fattening period (Kunz et al. 1998; McGuire et al. 2009). Hibernacula (or winter roosts) appear to be selected by bats for their high humidity and relatively stable, cool temperatures that are above freezing (Fenton 1970; Hitchcock 1949; Humphrey and Cope 1976). The duration of hibernation in the little brown myotis depends largely on climate and the length of the hibernal period for a given sector of its range. Although fidelity to hibernacula may differ between males and females (Thomas et al. 1979), little brown myotis often returns annually to swarm, mate, and hibernate at the same site (Davis and Hitchcock 1965; Humphrey and Cope 1976).

2. Spring, Summer, and Fall Habitat

In spring, little brown myotis form maternity colonies of reproductive female bats in barns, attics, tree cavities and other places that remain dark throughout the day (Crampton and Barclay 1998; Hitchcock and Davis 1965). These colonies range in size from tens to hundreds of individuals. Roost fidelity of females to summer roosts tends to be high with adult females typically returning to their natal roosts (Frick et al. 2010a; Reynolds 1998). Warm microclimates in maternity roosts help optimize gestation and postnatal growth of offspring (Baptista et al. 2000; Davis and Hitchcock 1965; Fenton 1970; Humphrey and Cope 1976; Kunz and Anthony 1982). Thus, non-reproductive females and adult males usually inhabit separate roosts individually or in small groups; information about the behavior of these cohorts during the active season is under-studied owing to difficulties of finding and monitoring these widely dispersed individuals.

The little brown myotis is opportunistic in selecting its roost sites, “taking shelter in any sites with appropriate microclimates, and quickly locating and exploiting new roosts” (Fenton and Barclay 1980). Flexible behavior may have led to the overall success of this species in exploiting fragmented agricultural landscapes (Henderson et al. 2009) and suburban areas with buildings that are frequently occupied during warm months, yet continued fragmentation of landscapes into smaller patches and reduced availability of buildings for roosting are certain to have adverse affects on little brown myotis populations.

E. Foraging

The little brown myotis feeds on small (3 - 10 mm) aerial insects (Anthony and Kunz 1977). Specifically, the diet of this species is comprised mostly of the insect orders Diptera, Lepidoptera, Coleoptera, Thrichoptera, Ephemeroptera, and Neuroptera with about the same frequency as these insects are available in the foraging area of bats (Anthony and Kunz 1977). In many areas, this bat feeds over open water and at the margins of bodies of water and forests (Anthony and Kunz 1977; Barclay 1991; Belwood and Fenton 1976; Fenton and Bell 1979; Saunders and Barclay 1992). However, foraging habitats appear to vary depending on intraspecific competition and flight ability. Juveniles tend to prefer foraging in clearings or open forest roads, whereas adults regularly forage in more cluttered environments (Crampton and Barclay 1998, van Zyll de Jong 1985). Adults also may prefer more open areas, especially when bat population density is high (Adams 1997).

The little brown myotis often engages in two or more feeding bouts per night, occupying remote night roosts to rest and digest between bouts (Anthony and Kunz 1977; Anthony et al. 1981; Kunz 1980). Foraging range for pregnant little brown myotis can exceed 30 hectares, but this range decreases during lactation when adult females return to the day roost to suckle young between evening and morning foraging bouts (Henry et al. 2002). Pregnant and lactating little brown myotis in New Hampshire consume, on average, 2.5 g and 3.7 g of aerial insects during their first nightly feeding bout, while juveniles consume 1.8 g during this same period (Anthony and Kunz 1977). During peak energy demands, lactating females are known to consume the equivalent of their body mass (ca 7 g) each night (Kunz 1980; Kurta et al. 1989).

F. Reproduction

The little brown myotis mates at swarming sites that also serve as hibernacula (Davis 1964; Davis and Hitchcock 1965; Fenton 1969; Hall and Brenner 1968; Kunz et al 1998; Schowalter 1980; Thomas et al. 1979). At these sites, bats copulate indiscriminately and promiscuously beginning in August, and males sometimes mate with torpid females throughout the hibernation period (Thomas et al. 1979). Some bats that visit a swarming site may relocate to alternative hibernacula prior to entering hibernation (Fenton 1969; Thomas et al. 1979). Thus, mating activity at swarming sites can lead to genetic mixing among roosting or hibernating colonies (Carmody et al. 1974). Females may be reproductively active during their first year of life, but males are not sexually mature until their second fall swarming opportunity (Thomas et al. 1979). Reproductive rates of females are high, averaging 95% from 1993 to 2008 (Frick et al. 2010a).

Female little brown myotis store sperm during both the autumn fattening and swarming period (Thomas et al. 1979) and during hibernation (Wimsatt 1944). Ovulation occurs within a few days of arousal from hibernation in spring (Buchanan 1987; Wimsatt and Kallen 1957) as long as females possess sufficient metabolizable fat reserves (Kunz et al. 1998). Subsequently, eggs may be fertilized by sperm that overwintered in the female reproductive tract. Gestation occurs over 50-60 days (Barbour and Davis 1969; Wimsatt 1945) depending on environmental conditions and physiological states of female bats (Racey 1973). Each successful pregnancy produces a single altricial offspring, or "pup" capable of clinging to the roost substrate and its mother's body with large thumbs, hind feet and deciduous incisors ("milk teeth"), but little else (Fenton 1970; Kurta et al. 1989; Wimsatt 1945). Reproductive success depends on the availability of insect prey during summer months coinciding with energetic demands of pregnancy and lactation (Anthony and Kunz 1977; Anthony et al. 1981; Frick et al. 2010a; Jones et al. 2003).

At birth, little brown myotis pups weigh about 25% of an adult female's post-partum mass and are about 43% of adult linear size (Burnett and Kunz 1982; Hayssen and Kunz 1996; Kunz and Anthony 1982). Young consume only milk prior to fledging around 22 days and 84% of adult body size (Burnett and Kunz 1982; Kunz and Anthony 1982; Powers et al. 1991). Pups supplement insect diets with milk until they are weaned at about 26 days (Kurta et al. 1989). Adult females often depart from maternity roosts to begin migrating to swarming sites once young are weaned, thus arriving at hibernacula earlier than yearlings (Kunz et al. 1998).

G. Hibernation

Between mid-August and mid-September in the northeastern United States, adult little brown myotis rapidly increase their body mass by over 2 g, which is about 30% of their prehibernating body mass (Kunz et al. 1998). Although the amount of fat deposited in autumn varies among age groups and sexes within sites, there is further variation throughout its geographic range (Ewing et al. 1970; Kunz et al. 1998; J.D. Reichard, unpublished data). Like many hibernators, bats may resist entering hibernation if they are unable to deposit sufficient white adipose tissue (WAT) reserves (Geiser 2004). However, many little brown myotis enter hibernation in thermally stable caves and mines with high humidity throughout their range when outside temperatures drop and insects become scarce. The timing of the onset of hibernation varies throughout the range of the species due to temperature differences and the length of the hibernation season (Humphries et al. 2002).

The little brown myotis selects hibernacula with relatively stable temperatures, typically ranging from 2-12ºC (Boyles and Willis 2009; Humphries et al. 2002; Thomas et al. 1990). Upon entering hibernation, body temperatures (T_b) drop to within 1-2ºC of the cave temperature while the bat is torpid (Geiser 2004). At this low T_b, metabolic rates decrease to 5-30% of basal metabolic rates, thus drastically conserving critical energy stored as WAT (Geiser 2004; Thomas et al. 1990). Considerably more WAT is conserved due to the reduction in thermoregulatory costs of a torpid bat (Boyles and Willis 2009; Thomas et al. 1990). However, during the hibernation period, individual bats periodically arouse to euthermic T_b for reasons that are not entirely understood (Boyles and Willis 2009; Geiser 2004; Thomas et al. 1990). Although arousal bouts typically make up < 1% of the total duration of hibernation, bats consume > 80% and perhaps as much as 95% of WAT reserves during these periods (Boyles and Brack 2009; Dunbar and Tomasi 2006; Thomas et al. 1990). It has been hypothesized that arousals are essential to excrete metabolic wastes, sleep, and/or drink (Thomas and Geiser 1997). Euthermia may also be an essential condition for mounting innate, inflammatory, and cell-mediated immune responses to various pathogens or foreign irritants (Prendergrast et al. 2002; M.S. Moore, personal communication). Healthy little brown myotis are known to arouse from torpor about every 12-15 days (Brack and Twente 1985, Thomas et al. 1995; Twente et al. 1985). Bats in general, and little brown myotis in particular, face extreme challenges in temperate climates where WAT reserves deposited to sustain torpor and arousal bouts through long winters present additional constraints on flight ability and energetic costs (Humphries et al. 2002; Kunz et al. 1998; Thomas et al. 1990). Thus, it is expected that bats have evolved to deposit precise WAT reserves to survive hibernation with respect to specific environmental conditions within their specific geographic ranges. Moreover, WAT reserves remaining at the end of hibernation are considered critical for successful ovulation and gestation (Krulin and Sealander 1972; Kunz et al. 1998; Polskey and Sealander 1979).

III. POPULATION STATUS

A. Core Range of the Species

The historic and current range of the little brown myotis covers portions of North America, including parts of Canada and central Mexico (Fenton and Barclay 1980). Individual bats surveyed in Mexico are found at higher elevations in forested areas (Findley and Jones 1967). Little brown myotis are not found in the northernmost parts of Canada and Alaska. In sum, the distribution of the little brown myotis spans from the southern limits of boreal forest habitat in southern Alaska and the southern half of Canada throughout most of the contiguous United States, excluding the southern Great Plains and the southeast area of California. In the southwestern part of the historic range of the little brown myotis, a formerly considered subspecies identified as *Myotis lucifugus occultus* is now considered a distinct species and named *M. occultus* (Piaggio et al. 2002; Wilson and Reeder 2005).

The little brown myotis is mostly absent from Florida and parts of the coast of the Carolinas and Virginia. A study of maternity colonies of the little brown myotis in Kentucky indicated that there are significantly fewer numbers in the southern and western U.S. range. (Davis et al. 1965).

> It reaches its greatest abundance in northern United States where it hibernates by the thousands in mines and caves in winter, and where large breeding colonies are easily located in old buildings in summer (Davis and Hitchcock, 1965). Southward the species becomes less common; few of the great caves of West Virginia, Tennessee, and Missouri harbor more than a few hundred in winter, and the species is rare in the caves of Georgia and Alabama (Davis et al. 1965).

Thus, the evidence suggests "that Kentucky may be near the edge of the summer range of *M. lucifugus* where the species becomes scarce and local." (Davis et al. 1965). Available literature indicates that the northeastern U.S. constitutes the core range for the species, and that population density substantially decreases moving southward and westward from that core range (Davis et al. 1965; Humphrey and Cope 1970). Indeed, while small populations of little brown myotis are able to persist in caves located intermittently throughout other parts of the species' range, the ideal hibernaculum conditions (temperature, moisture, geological composition, etc.) predominate in the northeastern region therefore making this core range where the overwhelming majority of the species (including most large wintering populations) resides.

For clarification purposes, the species' "core range" as used in this status review and in common scientific parlance is synonymous with, if not much broader than, the regulatory term "significant portion of its range." 16 U.S.C. § 1532(6). Indeed, not only does the northeastern core range cover a vast geographic area, but it is also where the large majority of little brown myotis have been reported. In addition, as described above, little brown myotis strongly prefer hibernacula meeting certain characteristics that are found much more readily in the northeastern U.S. than elsewhere in the species' range – meaning that this core range is critical to the species' overall survival because the vast majority of ideal habitat is found there, and thus species resiliency depends on little brown myotis continuing to populate and persist in this important habitat region. Thus, by any reasonable standard of quantitative or qualitative measurement, the northeastern core range is of paramount "significance" to the species' ultimate survival and recovery throughout its current and historical range.

B. Status

The little brown myotis has long been considered one of the most common and widespread bat species in North America. As of 2001 (IUCN) and 2003 (IUCN/SSC Action Plan), the status of this species was designated Lower Risk (Wilson and Reeder 2005). Long-term monitoring of 22 prominent hibernacula for the species in the core range in the northeastern U.S. provided the basis for cave survey data from 1985 to present to predict a population of 6.5 million little brown myotis as of 2006 (Frick et al. 2010b) – which is presumed to account for the vast majority of the species' overall population. As of 2006, regional mean growth suggested that the northeastern core population of this species was stable or slightly increasing (Frick et al. 2010b). Thus, the pre-WNS population of this species – both throughout its range and within its core northeastern range – was viable and did not face imminent risk of extinction.

However, as will be discussed in detail in the following section, the appearance of WNS in 2006 dramatically altered the population balance, which in turn has substantially impaired the ability of little brown myotis to adapt to other cumulative threats looming against a rapidly declining species baseline. In only four years, this lethal fungal pathogen has summarily killed at least one million little brown myotis in the northeastern core range, and all efforts undertaken thus far to contain its westward spread and rate of infection have proven ineffective. As such, the once-stable outlook for this species has quickly reversed, with emerging science projecting with near certainty that extinction will occur in the northeastern core range in a matter of years

(Frick et al. 2010b), with rangewide extinction likely to follow if effective measures are not implemented to slow, and ultimately halt, the disease's rapid spread and rampant mortality.

IV. LEGAL STANDARD FOR LISTING SPECIES UNDER THE ESA

The term "endangered species means any species which is in danger of extinction throughout all or a significant portion of its range." 16 U.S.C. § 1532(6). Thus, in evaluating various factors that bear on a listing decision, the FWS has a mandatory duty to list a species as endangered if it is found to be in danger of extinction throughout all of its range, or alternatively if the species is found to be in danger of extinction throughout a significant portion of its range. The evaluation and final listing determination must be made "solely on the basis of the best scientific . . . data available." 16 U.S.C. § 1533(b)(1)(A).

Pursuant to Section 4 of the ESA, 16 U.S.C. § 1533(a), the Interior Department must evaluate the following five factors in making a listing determination:

(A) the present or threatened destruction, modification, or curtailment of its habitat or range;
(B) overutilization for commercial, recreational, scientific, or educational purpose;
(C) disease or predation;
(D) the inadequacy of existing regulatory mechanisms; or
(E) other natural or manmade factors affecting its continued existence.

After considering the best available scientific evidence, listing is required where any single listing factor is satisfied. *See, e.g.*, 50 CFR § 424.11 (explaining that "[a] species shall be listed . . . if the Secretary determines, on the basis of the best scientific and commercial data available after conducting a review of the species' status, that the species is endangered or threatened because of any one . . . of the following factors"); *Nat'l Wildlife Fed'n v. Norton*, 386 F. Supp. 2d 553, 558 (D. Vt. 2005) ("Each [listing] factor is equally important and a finding by the Secretary that a species is negatively affected by just one of the factors warrants a non-discretionary listing as either endangered or threatened.").[1]

[1] While we submit that an endangered listing is required here in light of the best available scientific evidence (and strongly recommend an endangered listing status based on our professional opinions after reviewing the evidence), the listing inquiry to be undertaken by the FWS as part of its own status assessment necessarily encompasses the consideration of the species' listing as threatened. Moreover, the entire range of the little brown myotis must be listed if FWS determines that any one listing factor is satisfied because rangewide listing is *required* where either a species is found to be in danger of extinction throughout its entire range *or* a species is found to be in danger of extinction in a significant portion of its range. *See, e.g.*, 16 U.S.C. § 1532(6); *Defenders of Wildlife v. Salazar*, Civ. No. 09-77, 2010 U.S. Dist. LEXIS 80851 (D. Mont. Aug. 5, 2010).

V. THE FOLLOWING THREATS TO THE LITTLE BROWN MYOTIS WARRANT LISTING UNDER THE ESA

Novel diseases can, and often do, have serious impacts on naïve wildlife populations, which in turn can have significant impacts on ecosystem integrity (Frick et al. 2010b, Kilpatrick et al. 2009, McCallum et al. 2007). As illustrated by various species in recent years, infectious diseases increasingly serve as direct agents of local extirpations and rangewide extinctions of wildlife. Recent examples of such diseases demonstrating the need for immediate and effective action in the face of such outbreaks include amphibian extinctions from chytridiomycosis in the U.S. and abroad (Kilpatrick et al. 2009), rabbit extirpations from myxomatosis in the United Kingdom (Ross and Tittensor 1986), Tasmanian devil extirpations from infectious cancer (McCallum et al. 2007), and bird extirpations from West Nile Virus in North America (Peterson et al. 2004).

Indeed, such prior pandemics have led the FWS to act swiftly by implementing endangered listing statuses where diseases threaten species viability, timely affording affected species with the full protections of the ESA in an attempt to halt the trend toward extinction. *See, e.g.*, Determination That *Bufo hemiophrys* Baxter (Wyoming Toad) is an Endangered Species, 49 Fed. Reg. 1992 (Jan. 17, 1984) (listing the Wyoming Toad as endangered because of a "precipitous decline" in population later attributed to the chytrid fungus, *Batrachochtrium dendrobatidis*); Determination of Endangered Status for the Southern California Distinct Vertebrate Population Segment of the Mountain Yellow-Legged Frog (*Rana muscosa*), 67 Fed. Reg. 44832, 44388 (July 2, 2002) (listing the Mountain Yellow-Legged Frog as endangered in part because of the chytrid fungus, *Batrachochtrium dendrobatidis,* which the FWS determined "could be significantly detrimental" to the species); Emergency Determination of Endangered Status for the Mojave Population of the Desert Tortoise, 54 Fed. Reg. 32326 (Aug. 4, 1989) (listing the Mojave desert tortoise as endangered on an emergency basis due to Respiratory Disease Syndrome in order "to make Federal funding, protection, and other measures immediately available to combat the [pandemic]").

The little brown myotis, once considered a common bat species, is rapidly spiraling towards extinction as populations continue to contract the deadly fungal disease known as white-nose syndrome (WNS) at a rapid pace. WNS is a lethal and quickly spreading disease that many biologists have characterized as the greatest wildlife crisis of the past century. As emerging science has confirmed, the best available evidence conservatively predicts a 99% chance of little brown myotis extinction in the northeastern U.S. by at least 2026, and potentially much sooner depending on the actualized mortality rates that result as the disease continues its rapid spread (Frick et al. 2010b). Because of the importance of the little brown myotis in the ecology of the northeastern U.S., a regional population collapse is likely to "result in unpredictable changes to ecosystem structure and function" (Frick et al. 2010b). It is on this exigent basis that we strongly recommend and respectfully request an endangered listing for the little brown myotis pursuant to the ESA.

Additionally, in view of the grave threat posed by WNS which alone compels listing, other forms of mortality and harm to the little brown myotis exacerbate the acute effects inherent in the catastrophic WNS-caused population collapse. These additive forms of mortality further threaten the imperiled little brown myotis, and the existence of and impacts caused by these additive harms must be considered as part of the FWS's status assessment. When taken as a whole, the devastating effects of the WNS pandemic – coupled with additive forms of mortality to the species – plainly warrant listing under the ESA. 16 U.S.C. § 1533.

A. Disease or Predation

The overriding factor necessitating listing here is the disease/predation factor. 16 U.S.C. § 1533(a)(1)(C). Much like the recent extinctions and extirpations observed in other species by infectious diseases (*e.g.*, amphibians, rabbits, Tasmanian devils, and birds), WNS is devastating little brown myotis populations throughout the vast majority of their range.

As the best available science indicates, little brown myotis populations have been routinely extirpated near the epicenter of WNS in the northeastern U.S., and similar devastating extirpations throughout the species' range are expected to follow (Frick et al. 2010a; Frick et al. 2010b). Although the complete impact of WNS has not yet been realized, leading bat ecologists have concluded that with current trends, there is "a 99% chance of regional extinction of little brown myotis within the next 16 years" (Frick et al. 2010b). The emerging scientific conclusion that the little brown myotis is in imminent danger of extinction in at least a significant portion of its range is based on a thorough population viability analysis incorporating extensive empirical data collected before and since the appearance of WNS in the species' core range, including the species' starting population, vital rates, and observed morbidity rates as derived from a critical maternity colony near Peterborough, New Hampshire (Frick et al. 2010a; Frick et al. 2010b). This demographic dataset provided the model for the conservative conclusion that the little brown myotis will be extinct in its core range by 2026, if not sooner (Frick et al. 2010a; Frick et al. 2010b).

At present, more than one million bats have died from WNS, with the majority of those being little brown myotis. (A.C. Hicks, unpublished data). In four short years, the northeastern little brown myotis population has lost at least 15-20% of its population (Frick et al. 2010b). In light of this precipitous decline, as well as the scientific consensus that the species is "now experiencing unprecedented losses from WNS and facing a serious threat of regional extinction," immediate action is needed by the FWS to ensure its continued viability (Frick et al. 2010b).

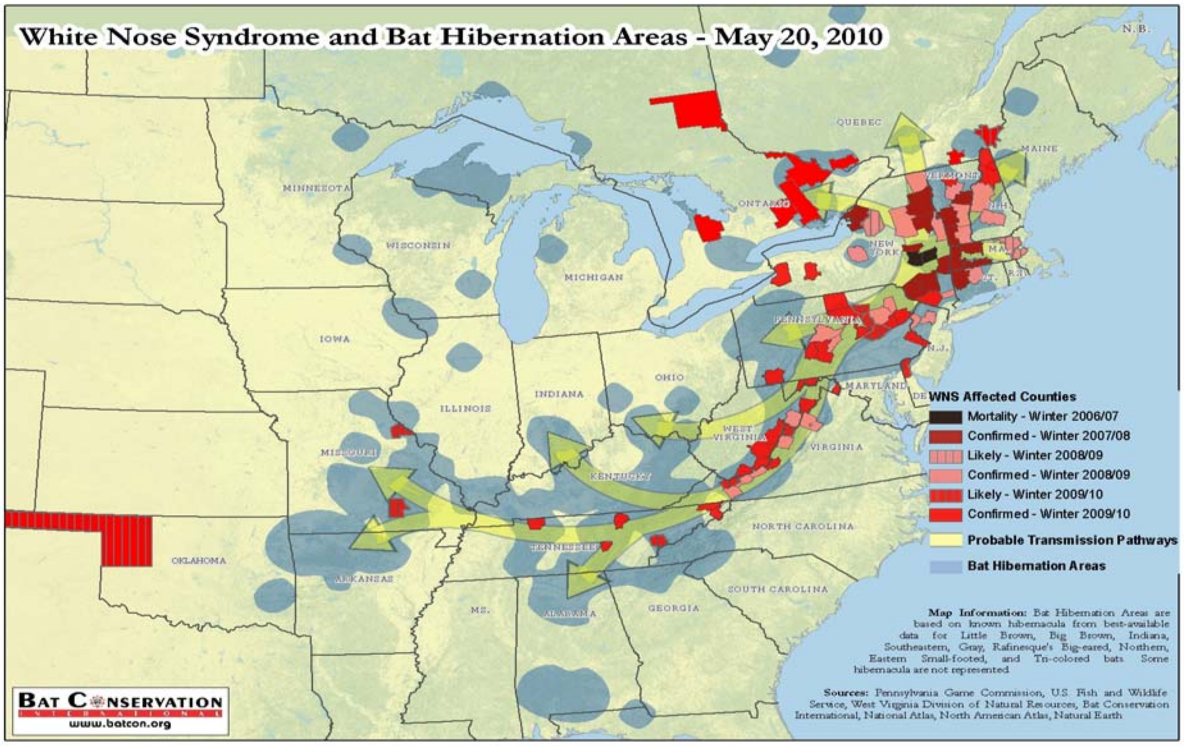
1. Origin, Cause, History, and Rapid Spread of WNS

Early symptoms of WNS were first observed at Howes Cave, west of Albany, New York, in February 2006, when a caver noticed and photographed a powdery white growth on the muzzle of a hibernating bat. Concern about WNS near Albany heightened in the winter of 2006-2007 when a hibernaculum survey team from the New York Department of Environmental Conservation discovered "hundreds of dead bats" in the cave (A.C. Hicks, pers. com.). White-nose syndrome was named after the characteristic white fungal growth becoming more and more evident on hibernating bats in the area.

*Little brown myotis with growth of the fungus causing WNS on its rostrum
Credit: Ryan von Linden, New York Dept. of Environmental Conservation

By the winter of 2007-2008, WNS was confirmed in four northeastern states and the characteristic fungus had been identified as a keratinophilic and psychrophilic fungus in the genus *Geomyces* (Blehert et al., 2009). *Geomyces destructans* was subsequently confirmed as a new species in 2009 (Gargas et al. 2009) and as of June 2010 had been isolated from bats in 14 states in the U.S. (Vermont, New Hampshire, Massachusetts, New York, Connecticut, New Jersey, Delaware, Pennsylvania, Maryland, Virginia, West Virginia, Tennessee, Missouri, and Oklahoma) and from two Canadian provinces (Ontario and Quebec) – reaching more than 2500 km from Albany, New York in only four years (C. Butchkowski , pers. comm.). The fungal pathogen, *G. destructans*, has also been isolated from at least five bat species in Europe (Peuchmaile et al. 2010; Wibbelt et al. 2010), but there are still unanswered questions about the specific origin of the fungus. Bats that succumb to WNS exhibit lesions on the skin of their wings, face, and ears (Meteyer et al. 2009, Courtin et al. 2010), which may persist into the active season on bats that survive hibernation (Cryan et al. 2010; Reichard and Kunz 2009). Bats at WNS-affected sites also appear to deplete their essential fat reserves well before the end of the typical hibernation period (J. D. Reichard, unpublished data).

The direct role of *G. destructans* in WNS is still being investigated. However, evidence suggests that this fungus plays a leading role in causing mortality either through indirect impact on hibernation physiology (Boyles and Willis 2009) or more direct pathogenic mechanisms (Cryan et al. 2010; Meteyer et al. 2009). Currently, it is thought that *G. destructans* is spread mainly through bat-to-bat contact, however, transmission by humans has not been ruled out. The pattern of spread has followed predictable trajectories along putative migratory pathways and overlapping summer ranges of hibernating bat species.



*Geographic Spread of WNS Since 2006. Credit: Bat Conservation International

It is expected that affected bats will come into contact with healthy bats during any one of several possible scenarios. Three leading hypotheses are: 1) bats that hibernate at affected sites may have overlapping summer ranges with bats that hibernate in unaffected sites, 2) bats may swarm at affected sites before migrating to nearby unaffected sites, and 3) unaffected young bats or previously unexposed adult bats may aggregate with affected bats at hibernacula. Secondary hypotheses include transmission by human or other non-bat animal vectors.

Although disappearance of bats from affected hibernacula and scavenging of bat carcasses may compromise precise estimates of the impact of WNS on little brown myotis populations, the scientific consensus is that more than one million little brown myotis (or approximately 15% of the estimated pre-WNS regional population) have succumbed to this lethal disease from 2006 to 2009 (Frick et al. 2010b). In part due to its relative abundance in northeastern North America, the little brown myotis has shown the greatest mortality of all bat species found at affected hibernacula (Frick et al. 2010b), although at least four other species (*Myotis septentrionalis*, *Myotis sodalis*, *Myotis leibii* and *Perimyotis subflavus*) have also experienced severe mortality at hibernacula in the northeastern U.S. (A.C. Hicks and K.E. Langwig, pers. comm.). Scientists have entered hibernacula and discovered hundreds or thousands of carcasses on cave floors during winter and post-winter counts. Other colonies have vanished from long-standing hibernacula without leaving much trace of previous presence by bats (T. French, pers. comm.), except for a handful of carcasses in various stages of decomposition. The mortality associated with WNS at particular hibernacula in the species' core range has been staggering. The annual mean mortality in affected caves is 73%, with many hibernacula reaching 99% mortality or total extirpation in either the first year of infection or over multiple years (Frick et al. 2010b).

*Little brown myotis carcasses littering floor of Aelous Cave, VT
Credit: Jonathan D. Reichard, Boston University

For example, Aeolus Cave in East Dorset, Vermont used to support the largest little brown myotis hibernaculum in New England, with historic estimates of approximately 300,000 individuals in winter, or nearly 4% of the species' entire population (Hitchcock 1960). However, only a fraction of the pre-WNS little brown myotis population remains as of 2010, which scientists project to be a loss of far more than 90% at this critical hibernaculum. Similarly, Graphite Mine in Hague, New York – once home to 185,000 little brown myotis – now contains less than 2,000 members of the species, or approximately 1% of its pre-WNS population. This trend is occurring across the species' core range (and quickly replicating in other parts of its range) at hibernacula with populations large and small, leaving many of the most important winter refuges for the species with non-existent or unsustainable little brown myotis populations within a very short period from the time of first infection.

2. Pathology of Geomyces destructans on Little Brown Myotis

Bats infected with *G. destructans* have been observed exhibiting some or all of the following abnormal behaviors or symptoms:

- Presence of a white, psychrophilic, keratinophilic fungus (*Geomyces destructans*) on the face, ears, and wing membranes of bats. The hyphae of this WNS-associated fungus is known to penetrate the dermis of affected bats, eroding wing and ear tissue. The hyphae extends into hair follicles and sebaceous glands, compromising their function and eventually reaching the underlying tissue (Cryan et al. 2010), although no local inflammation or immune response has been reported in this or other hibernating bat species (Blehert et al. 2009; Courtin et al. 2010; Gargas et al. 2009; Meteyer et al. 2009).

- Depleted white fat reserves during hibernation. Starvation due to depleted fat reserves may be the proximate cause of death for bats affected by WNS. WNS-affected bats at some sites have poorer body condition (lower BMI, less stored fat*)* in summer *and* winter, and are generally significantly smaller throughout the reproductive period in 2008 than they were in 1975 (Kunz et al. 2008; J.D. Reichard unpublished data). Concerns have been raised that even bats that survive exposure to *G. destructans* during the hibernation period will be unable to reproduce and raise young successfully, further imperiling populations.

- Reduced capacity to arouse from deep torpor. Numerous researchers have observed that bats hibernating in WNS-affected sites are less likely to respond to anthropogenic disturbances; typically, bats will arouse from torpor soon after people enter a cave or mine, but affected little brown myotis fail to arouse to euthermic states amid anthropogenically-generated noise in the hibernacula (A.C. Hicks, 2008, M.S. Moore, pers. comm.). Infrared thermal imaging of hibernating clusters of little brown myotis confirms that most torpid bats in affected sites do not elevate body temperature when disturbed (J. D. Reichard; J.G. Boyles unpublished data).

- Changes in immune response during hibernation. Immune function may be intrinsically depressed in all hibernating animals, including little brown myotis (Carey et al. 2003, M.S. Moore, pers. comm.). However, there is evidence that immune function is irregular in hibernating bats affected with WNS (M.S. Moore, unpublished data; Jacob and Reeder, unpublished data). Numerous assays have been used to measure immune response, leading to a variety of conclusions. While complement proteins in blood from WNS-affected little brown myotis are better at killing gram negative bacteria, *Escherichia coli*, and gram-positive bacteria, *Staphylococcus aureus*, they appear to be worse at killing fungus, *Candida albicans*, compared to unaffected little brown myotis (M.S. Moore, unpublished data WNS-affected little brown myotis have significantly reduced antioxidant levels, but higher levels of circulating leucocytes and immunoglubulins than unaffected bats during certain periods of hibernation (M.S. Moore, personal communication). While innate immunity (less energetically costly) seems to be unchanged or even slightly upregulated in WNS-affected individuals, adaptive immunity (energetically expensive) may be significantly suppressed in bats from unaffected sites (D.M. Reeder, personal communication). "Little brown myotis does not mount an effective, morphologically detectable inflammatory response to [*G. destructans*]" (E. Buckles, pers. comm..) and cutaneous inflammatory response may be particularly low during hibernation (M.S. Moore pers. comm..). It is also evident that immune responses during hibernation are also affected by body composition (*i.e.*, fat reserves and water content), thus suggesting an interaction between the physiological response of bats to infection and subsequent immunological responses (M.S. Moore, personal communication). The immunological and physiological mechanisms behind these differences are not yet fully known.

- Ulcerated, scarred, or necrotic wing membrane tissue. "WNS-affected bats sampled in spring and summer show extensive wing damage in the form of scarred and necrotic tissue (Meteyer et al. 2009; Reichard and Kunz 2009). Though some reports indicate that mild scarring or tissue necrosis of wing membranes may heal in the summer season (N.W. Fuller, unpublished data), many bats captured in the active season show substantial damage that may compromise flight ability and potentially make the bat susceptible to predation or poor foraging success, supported by evidence of low body mass in bats with severely damaged wings (Reichard and Kunz 2009). Up to 61% of little brown myotis monitored at two New Hampshire maternity colonies in the summer of 2008 had severe wing damage, presumably from WNS infection or from frost bite in the previous winter (Reichard et al., 2009). Poor foraging success, resulting from damaged wings, after emerging from hibernation with depleted fat reserves is likely to negatively affect the reproductive success of female little brown myotis.

- Atypical behavior of hibernating little brown myotis in the form of frequent arousal bouts during hibernation and early emergence from hibernation. Healthy bats typically arouse from torpor at 13 to 15-day intervals (most studies suggest that this periodic arousal serves to maintain immune function – in deep torpor, immune response is negligible), but WNS-affected bats have been observed to awaken and become active as frequently as every 2 – 4 days (WNS March 2009 Status Report, W. Kilpatrick, pers. comm.). Each arousal requires the expenditure of substantial energy reserves, both for thermogenesis and for movement (Boyles and Willis 2009). The reason for increased arousals in WNS-affected bats has not been conclusively established, but hypotheses include: irritation by fungal infection prompts bats to awaken prematurely; fungal infection prompts bats to awaken to enhance immune function; as winter goes on and energy reserves dwindle, bats may break torpor more frequently to feed and thus restore lost energy reserves; evidence for the latter hypothesis is strong as bats are often observed leaving hibernacula in mid-winter as if to forage. This behavior is, with few exceptions, fatal. Even if the increased frequency of arousals observed in WNS-affected bats serves to enhance immune function, this benefit is offset by the massive energy requirements involved in these arousals (D.M. Reeder, pers. comm.).

3. Prediction of Population Collapse and the Necessary Federal Response

As we have explained in this status review, emerging scientific evidence analyzing the current trend of WNS conservatively predicts a 99% chance of extinction throughout the core range of the little brown myotis in the next 16 years, if not sooner (Frick et al. 2010b). This extirpation crisis "paints a grim picture of a once-healthy population of an abundant and widely distributed species now experiencing unprecedented losses from WNS and facing a serious threat of regional extinction . . . [that] may result in unpredictable changes to ecosystem structure and function" (Frick et al. 2010b).

Accordingly, in view of our analysis of the available information on WNS and its devastating impact on the little brown myotis, we strongly recommend that the Service list the species as endangered in a timely manner pursuant to the mandates of the ESA after completing its own status assessment, in order to effectuate all conservation and recovery efforts necessary ensure the species' ultimate survival and recovery.

B. Present or Threatened Destruction, Modification, or Curtailment of Habitat

The perilous decline of the little brown myotis from WNS is further exacerbated by likely additive forms of mortality and other types of harm. For example, the many forms of habitat destruction that fragment the species' range have a far more acute impact now in light of WNS as extirpations lead to more isolated and more heavily fragmented populations, making the species even more susceptible to extinction. Thus, the impact of habitat destruction, modification, and curtailment should also be considered in the FWS's status assessment. 16 U.S.C. § 1533(a)(1)(A).

The rapid expansion of wind energy development throughout the United States – and particularly throughout the core range of the little brown myotis – presents an additional threat to little brown myotis populations. The mortality risk to bats posed by wind turbines through collision risk and barotrauma risk is well-documented (Arnett et al. 2008; Baerwald et al. 2008; Cryan et al. 2009; Kunz et al. 2007). *See Animal Welfare Inst. v. Beech Ridge Energy*, 675 F. Supp. 2d 540 (D. Md. 2009). There have been thousands of documented little brown myotis deaths despite the limited nature of post-construction monitoring occurring at operating wind facilities. Indeed, conservatively assuming the installed capacity of 2,612 MW in ten eastern states (see www.windpoweringamerica.gov/wind_installed_capacity), and an average fatality rate of 30.1, of which 6.4% of these kills were little brown myotis (Arnett et al. 2008; Tables 1 and 2), 4,717 individuals of this species are projected to have been killed in 2010 alone in only these ten states. Recent monitoring efforts indicate even higher fatality rates (approximately 25%-30% of total bat deaths) for little brown myotis at some facilities in the eastern U.S. (E.B. Arnett, Bat Conservation International, unpublished data) and the Midwest (Gruver et al. 2009).

Moreover, some scientists suspect that WNS-affected bats could be more susceptible to death by turbine collision or barotrauma because WNS-affected bats typically show extensive wing damage, meaning that their flight ability is substantially compromised and consequently their capacity to avoid operational turbines may be significantly reduced (Reichard and Kunz 2009; D.M. Reeder, pers. comm.). Also, the vast construction of wind turbines creates significant amounts of edge habitat – where little brown myotis are known to forage – and could potentially create a sink effect by attracting higher numbers of this species into proximity with wind turbines, which could in turn substantially increase wind energy related mortality. Thus, even in the absence of WNS, wind turbines pose an important threat to populations of this species that must be considered in the agency's status assessment and decision-making.

Other prominent examples of habitat destruction or modification that negatively affect the little brown myotis, further worsening the effects of the WNS pandemic, include commercial timber harvesting (Cheever and Balster 2004); oil, gas, and mineral extraction/development; conversion of wetlands and riparian zones to other uses; and residential and commercial development, among other habitat-affecting activities. These activities, combined with the WNS crisis, counsel in favor of an ESA listing to ensure that all forms of additive mortality are minimized and mitigated unless and until an effective strategy for the species' survival can be implemented and its objectives can be fully achieved.

C. Other Natural or Manmade Factors affecting its Continued Existence

Other natural and manmade factors also have an adverse impact on the little brown myotis – an impact that is ever more acute against a rapidly declining species baseline in light of WNS. These factors must also be considered as part of the FWS's status assessment. 16 U.S.C. § 1533(a)(1)(E).

The most notable example of a manmade or natural factor affecting the species' survival is anthropogenic climate change. The consequence of reduced precipitation during summer months in the species' core range could have major consequences for the survival of juvenile and adult bats (Adams and Hayes 2008; Frick et al. 2010a). A surprising conclusion drawn from a recent scientific study is a direct correlation between cumulative summer precipitation and the probability of little brown myotis survival (Frick et al. 2010a). The latter study demonstrated that the variance of cumulative precipitation significantly correlated with population highs and lows. The underlying premise linking climate change/precipitation variances to little brown myotis survival probability is the reduced availability of food sources during the important foraging months in autumn before the onset of hibernation. During this time, little brown myotis must build up their important fat reserves in order to survive through hibernation. However, unlike during times of high precipitation, reduced precipitation results in reduced abundance of insects and other prey (Frick et al. 2010a). Thus, the expected summer drying of the northeastern U.S. as a result of climate change is likely to negatively affect survival of little brown myotis, and particularly adult females who must feed themselves and their pups (Frick et al. 2010a). In addition, climate change plays a role by drying up traditional water sources (via warmer temperatures and reduced precipitation) that serve as foraging grounds for the little brown myotis, meaning that in years of drought female reproduction will drop significantly and the population will be further strained (Adams and Hayes 2010).

Other examples of manmade or natural factors adversely impacting the little brown myotis against a severely declining baseline include pesticide spraying for agricultural and residential use that leads to toxic effects on little brown myotis (Anthony and Kunz 1977; Clark et al. 1978; Fenton and Barclay 1980; Kunz et al. 1977); dumping of non-source pollutants such as PCBs that have toxic effects on little brown myotis and their prey (Fenton and Barclay 1980; *Damage, Assessment, Remediation, and Restoration, DARRP*, Program of the NOAA Northeast Region 2010); and dumping of other chemicals and industrial byproducts such as cyanide and mercury into water bodies where little brown myotis forage on affected prey (Driscoll et al. 2007). The combined effect of these various natural or manmade factors, particularly in combination with the WNS crisis, demonstrates the need for immediate and effective protection of the little brown myotis pursuant to the mandates of the ESA.

D. The Inadequacy of Existing Regulatory Mechanisms

The WNS pandemic has shown no signs of slowing down, and according to the best available science, regional extinction of the core northeastern population will occur by 2026, if not sooner (Frick et al. 2010b). Despite a variety of federal and state laws that generally protect the environment and wildlife, there is simply no existing regulatory or legal mechanism sufficiently protective of bats, much less any mechanism for protecting a bat species on the precipice of extinction to ensure its ultimate survival and recovery. On the basis of this legal and regulatory vacuum that wholly fails to protect the species, we strongly recommend listing to ensure that appropriate resources and conservation efforts are maximized to give the little brown myotis the optimal chance of species survival. 16 U.S.C. § 1533(a)(1)(D).

Although traditional federal and state laws do not address impacts to the little brown myotis or the WNS crisis, recent efforts by federal and state governments have been made to curtail the spread of WNS. For example, the FWS released a draft Structured Decision Making Initiative in October 2009 that reported on various conservation measures that could be implemented in non-affected regions to prevent WNS from entering new hibernacula in new states (Szymanski et al. 2009). In July 2010, certain western field offices of the U.S. Forest Service implemented emergency closures of caves within particular national forests. In August 2010, the Bureau of Land Management decided to take a case-by-case cave closure approach, but encouraged the public to avoid caves on BLM lands. On September 13, 2010, the FWS closed all caves in the National Refuge System. On October 21, 2010, the FWS issued a draft WNS National Plan directed at federal agencies, state agencies, and tribes. Additionally, many states have followed the federal lead and have implemented some cave closures on state-owned lands.

Despite these efforts, WNS continues to devastate little brown myotis populations throughout the species' core range. This is not only because efforts to date tend to be stopgap measures focusing primarily on curtailing the further spread of WNS into new areas (and thus necessarily focus less on the core range of the species), but also because, short of listing under the ESA, federal efforts can necessarily only influence decisions about and conservation on federal lands – lands that comprise a very small portion of habitat within the core range of the species. Indeed, in the core range of the species, far more than 90% of the land is privately owned, meaning that current federal and state efforts are unable to fully, or even substantially, address this crisis in the vast majority of the species' habitat. Thus, despite the best efforts of federal and state agencies, it is imperative that the little brown myotis be listed under the ESA so that all actors – federal, state, municipal, and private – are required to satisfy the Congressional mandate in the ESA to afford the species the greatest protection under the statute, including, for example, the substantive and procedural protections required by sections 7 and 9 of the Act, 16 U.S.C. §§ 1536, 1538, in order to best ensure its ultimate survival and recovery. Accordingly, the patent inadequacy of current legal and regulatory mechanisms to cure WNS, much less to effectively stop its rapid spread into previously uninfected hibernacula, counsels in favor of a timely listing of the little brown myotis upon the Service's completion of a status assessment, and supports our recommendation of an endangered listing.[2]

VI. THE LITTLE BROWN MYOTIS WARRANTS EMERGENCY LISTING UNDER THE ESA

Due to the unprecedented mortality of little brown myotis and the rapidly declining status of the species due to the WNS pandemic, we additionally recommend emergency listing for the species pursuant to section 4(b)(7) of the ESA. 16 U.S.C. § 1533(b)(7); 50 C.F.R. 424.20. The ESA authorizes the FWS to issue a temporary emergency listing for species when there is evidence of "any emergency posing a significant risk to the well-being of any species." 16 U.S.C. § 1533(b)(7). By way of amendment to the ESA in 1988, Congress "directed the [FWS] to . . . make prompt use of the authority [to issue emergency listing regulations] to prevent a significant risk to the wellbeing of any such species." 16 U.S.C. § 1533(b)(3)(C)(iii).

Here, emergency listing is warranted because the WNS crisis and its devastating impacts to this species plainly constitute an emergency "posing a significant risk to the well-being of" the little brown myotis. 16 U.S.C. § 1533(b)(7). Indeed, the best available science predicts near-certain regional extinction in the species' core range by approximately 2026, if not before (Frick et al. 2010b). Particularly in light of (1) the devastating impact of WNS on the species, (2) the fact that no cure has been discovered, (3) curtailment efforts to date have failed to contain the disease's rapid spread, and (4) various other manmade and natural threats (wind turbines, climate change, pesticides, adverse habitat modification, etc.) that exacerbate the effects of WNS and make the species even more vulnerable against a rapidly declining baseline, an emergency listing is clearly warranted here.

An analogous situation to the WNS crisis affecting the little brown myotis is the Respiratory Disease Syndrome that acutely impacted the Mojave desert tortoise in the late 1980's. On August 4, 1989, in response to a listing petition, the FWS promulgated an emergency regulation listing the Mojave desert tortoise as endangered on an emergency basis, finding that "an emergency posing a significant risk to the well-being of the desert tortoise exists as a result of the outbreak and rampant spread of a contagious disease that is often, and may always be, fatal and for which no known cure currently exists." 54 Fed. Reg. 32326 (Aug. 4, 1989). With the onset of the lethal respiratory disease, in addition to other exacerbating factors threatening the declining species, it was the "cumulative dangers that compelled emergency listing" of the desert tortoise. *Las Vegas v. Lujan*, 891 F.2d 927, 930 (D.C. Cir. 1989). Importantly, the primary rationale underlying the FWS's emergency listing – and thus the agency's sole basis for finding "that good cause exists" to support an emergency listing – was

[2] While the primary emphasis of this status review focuses on the WNS pandemic and the inadequacy of existing regulatory mechanisms related to that crisis, we note that there are also not adequate mechanisms for objectively addressing many of the compounding factors such as climate change and wind turbine mortality.

"the need to make Federal funding, protection, and other measures immediately available to combat the Respiratory Disease Syndrome." 54 Fed. Reg. 32326.

Accordingly, we recommend an emergency listing of the little brown myotis here to ensure immediate federal funding, legal protection, conservation efforts, and other measures as part of a dedicated recovery program that will maximize the probability of the little brown myotis's ultimate survival, during the time necessary for the Service to conduct its status assessment. Without such an emergency listing, valuable time will be lost that could otherwise be devoted to seeking a cure for WNS, strengthening measures to contain the disease's spread, bolstering efforts of private and governmental actors to conserve the species and its habitat as opposed to exacerbating WNS's impacts through deleterious activities, and funding cutting-edge scientific research on infectious diseases in little brown myotis and other bat populations. Therefore, we recommend and respectfully request that the FWS invoke its authority under section 4(b)(7) of the ESA to list this species on an emergency basis while the agency conducts its status assessment.

VII. CONSERVATION RECOMMENDATIONS & DESIGNATION OF CRITICAL HABITAT

As noted in the previous section, an important measure that should be expeditiously implemented is the appropriation of federal funding for research on WNS and particularly research aimed at finding the ultimate cure to the disease before the pandemic leads to extinction. In addition, secondary funding should be allocated for mitigation and management of WNS, as well as for mitigation of exacerbating factors further impacting the species (*e.g.*, wind turbines, climate change, development, etc.).

As a means to providing much-needed protection for the species, we also strongly recommend that critical habitat be designated concurrently with listing – in the event that the Service concurs in its status assessment with our conclusion that listing is warranted here. 16 U.S.C. § 1533(a)(3)(A) (requiring that, to the maximum extent prudent and determinable, the FWS designate critical habitat concurrent with listing); 50 CFR § 424.12(a). At bare minimum, important winter hibernacula meeting a minimum population threshold of little brown myotis should be designated as critical habitat (similar to that which has been designated for Indiana bats and Virginia big-eared bats). In addition, maternity colony roosts, and important roosting and foraging habitat should be designated as critical habitat to protect the species during non-hibernation periods. In short, the FWS should designate as critical habitat those areas known to be important refugia for the little brown myotis, in order to best ensure the ultimate survival and recovery of this species.

VIII. CONCLUSION

The little brown myotis is suffering from a devastating pandemic in WNS. The best available scientific evidence has conservatively projected with 99% certainty that the WNS crisis will cause a population collapse in the core range of the little brown myotis by 2026, if not sooner (Frick et al. 2010b). Other forms of additive mortality further threaten this species and result in ever more acute effects on the rapidly declining baseline. This extraordinary situation compels urgent action by the FWS.

Accordingly, based on that evidence as well as our analysis in this status review, we urge the FWS to immediately conduct its own status assessment, and we recommend promulgation of an endangered listing for the little brown myotis upon completion of that review. *See* 16 U.S.C. § 1533(a). In addition, we also strongly recommend that the Service promulgate an interim regulation listing the little brown myotis as endangered on an emergency basis, due to the alarmingly high rate of mortality at hibernacula throughout its range, and particularly in its most critical northeastern core range. *Id.* § 1533(b)(7).

In sum, this is a pandemic with imminent and catastrophic consequences of a magnitude rarely if ever seen in the wildlife community, and thus the ultimate viability of the little brown myotis might very well hinge on how quickly and how effectively the FWS acts in completing a status assessment and implementing the recommendations of this status review. As such, we respectfully request that the Service undertake a biological status assessment immediately, and that it act swiftly upon completion of that assessment to protect this species pursuant to its authority under the ESA.

IX. LITERATURE CITED

Adams, R.A., and M. A. Hayes. 2008. Water availability and successful lactation by bats as related to climate change in arid regions of western North America. Journal of Animal Ecology, DOI: 10.1111/j.1365-2656.2008.01447.x

Anthony, E.L.P., and T.H. Kunz. 1977. Feeding strategies of the little brown bat, *Myotis lucifugus*, in southern New Hampshire. Ecology, 58:775-786.

Anthony, E.L.P., M.H. Stack, and T.H. Kunz. 1981. Night roosting and the nocturnal time budgets of the little brown bat, *Myotis lucifugus*: effects of reproductive status, prey density, and environmental conditions. Oecologia, 51:151-156.

Arnett E.B., W.K. Brown, W.P. Erickson, J.K. Fiedler et al. 2008. Patterns of bat fatalities at wind energy facilities in North America. Journal of Wildlife Management, 72: 61-78.

Baerwald. E.F., G.H. D'Amours, B.J. Klug and R.M.R. Barclay. 2008. Barotrauma is a significant cause of bat fatalities at wind turbines. Current Biology, 18: R695-696.

Baptista, T.L., C.S. Richardson, and T.H. Kunz. 2000. Growth rates and age estimation in free-ranging bats: a comparison of longitudinal and cross-sectional sampling methods. Journal of Mammalogy, 81:709-718.

Barbour, R.W. and W.H. Davis. 1969. Bats of America. University Press of Kentucky, Lexington, Kentucky.

Barclay, R.M.R., D.W. Thomas, and M.B. Fenton. 1980. Comparison of methods used for controlling bats in buildings. Journal of Wildlife Management, 44: 502-506.

Barclay, R.M.R. 1991. Population structure of temperate zone insectivorous bats in relation to foraging behaviour and energy demand. Journal of Animal Ecology, 60: 165-178.

Belwood, J.J., and M.B. Fenton. 1976. Variation in the diet of *Myotis lucifugus* (Chiroptera: Vespertilionidae). Canadian Journal of Zoology, 54: 1674-1678.

Blehert, D.S., A.C. Hicks, M. Behr, C.U. Meteyer, B.M. Berlowski-Zier, E.L. Buckles, J.T.H. Coleman, S.R. Darling, A. Gargas, R. Niver, J.C. Okoniewski, R.J. Rudd, and W.B. Stone. 2009. Bat white-nose syndrome: An emerging fungal pathogen? Science, 323: 227.

Boyles, J.G. and C.K.R. Willis. 2009. Could localized warm areas in cold caves reduce mortality of hibernating bats affected by white-nose syndrome? Frontiers in Ecology and the Environment, doi:10.1890/080187.

Boyles, J.G. and V. Brack, Jr. 2009. Modeling survival rates of hibernating mammals with individual-based models of energy expenditure. Journal of Mammalogy, 90: 9-16.

Brack, V., Jr., and J.W. Twente. 1985. The duration of the period of hibernation of three species of vespertilionid bats. I. Field studies. Canadian Journal of Zoology, 63: 2952-2954.

Buchanan, G.D. 1987. Timing of ovulation and early embryonic development in *Myotis lucifugus* (Chiroptera: Vespertilionidae) from northern central Ontario. American Journal of Anatomy, 178: 335-340.

Buck, E.H., and M.L. Corn, P. Baldwin 2007. *The Endangered Species Act and "Sound Science,"* Congressional Research Service Report for Congress, January 8, 2007.

Burnett, C.D., and T.H. Kunz. 1982. Growth rates and age-estimation in two temperate zone bats: a comparison of *Eptesicus fuscus* and *Myotis lucifugus*. Journal of Mammalogy, 63: 33-41.

Carey H., M.T. Andrews, and S.L. Martin. 2003. Mammalian hibernation: Cellular and molecular responses to depressed metabolism and low temperature. Physiological Reviews, 83: 1153-1181.

Carmody G.R., M.B. Fenton, and D.S.K. Lee. 1971. Variation of body weight and proteins in three Ontario populations of hibernating *Myotis lucifugus lucifugus* (LeConte) (Chiroptera: Vespertilionidae). Canadian Journal of Zoology, 49: 1535-1540.

Clark, D.R., Jr., T.H. Kunz, and T.E. Kaiser. 1978. Insecticides applied to a nursery colony of little brown bats (*Myotis lucifugus*): lethal concentrations in brain tissue. Journal of Mammalogy, 59: 84-91.

Clark, D.R., Jr., T.H. Kunz, and T.E. Kaiser. 1978. Insecticides applied to a nursery colony of little brown bats (*Myotis lucifugus*): lethal concentrations in brain tissue. Journal of Mammalogy, 59: 84-91.

Conniff, Richard. 1991. *The Cave of the Bats*, Yankee Magazine, February, 1991.

Courtin, F., W.B. Stone, G. Risatti, K. Gilbert, and H.J. Van Kruiningen. 2010. Pathologic findings and liver elements in hibernating bats with white-nose syndrome. Veterinary Pathology, 47: 214-219.

Crampton, L.H. and R.M.R.Barclay. 1998. Selection of roosting and foraging habitats by bats in different-aged aspen mixedwood stands. Conservation Biology, 12: 1347-1358.

Cryan, P.M., and R.M.R. Barclay. 2009. Causes of bat fatalities at wind turbines: Hypotheses and predictions. Journal of Mammalogy, 90: 1330-1340.

Cryan, P.M., C. U. Meteyer, J,G, Boyles, and D.S Blehert. 2010. Wing pathology of white-nose syndrome in bats suggests life-threatening disruption of physiology. BMC Biology, 8:135, doi:10.1186/1741-7007-8-135.

Culver, D.C., H.H. Hobbs III, M.C. Christman, and L.L. Master. 1999. Distribution map of caves and cave animals in the United States. Journal of Cave and Karst Studies, 61: 139-140.

Darling, S. R. 2009. Statement: White-Nose Syndrome: what is killing bats in the Northeast? Testimony from the hearing before the U.S. House of Representatives Committee on Natural Resources, Subcommittee on National Parks, Forests, and Public Lands, and Insular Affairs, Oceans, and Wildlife, June 4th, in Washington, D.C.

Daszak, P., A.A. Cunningham, and A.D. Hyatt. 2000. Emerging infectious diseases of wildlife–threats to biodiversity and human health. Science, 287: 443-449.

Davis, W.H. 1964. Winter awakening patterns in the bats *Myotis lucifugus* and *Pipistrellus subflavus*. Journal of Mammalogy, 45: 645-647.

Davis, W. H., and H.B. Hitchcock. Biology and migration of the bat, *Myotis lucifugus*, in New England. Journal of Mammalogy, 46: 296-313.

Davis, W.H., M.D. Hassell, and M.J. Harvey. Maternity colonies of the bat *Myotis l. lucifugus* in Kentucky. American Midland Naturalist, 73: 161-165.

de Castro, F., and B. Bolker. 2005. Mechanisms of disease-induced extinction. Ecology Letters, 8: 117-126.

Dewey, T., N. Shefferly, and A. Havens. 2010 Animal Diversity Web. University of Michigan Museum of Zoology.

Driscoll, C.T., Y-J Han, C.Y. Chen, D.C. Evers, K. Fallon Lambert, T.M. Holsen, N.C. Kamman, and R.K. Munson. 2007. Mercury contamination in forest and freshwater ecosystems in the Northeastern United States. BioScience, 57: 17-28.

Dunbar, M.B., and T.E. Tomasi. 2006. Arousal patterns, metabolic rate, and an energy budget of eastern red bats (*Lasiurus borealis*) in winter. Journal of Mammalogy, 87: 1096-1102.

Ewing, W.G., E.H. Studier, and M.J. O'Farrell. 1970. Autumn fat deposition and gross body composition in three species of *Myotis*. Comparative Biochemistry and Physiology, 36: 119-129.

Fellers, G.M., D.E. Green, and J.E. Longcore. 2001. Oral chytridiomycosis in the mountain yellow-legged frog (*Rana muscosa*). Copeia, 2001: 945-953

Fenton, M.B. 1969. Summer activity of *Myotis lucifugus* (Chiroptera: Vespertilionidae) at hibernacula in Ontario and Quebec. Canadian Journal of Zoology, 47:597-602.

Fenton, M.B., and G.P. Bell. 1979. Echolocation and feeding behaviour in four species of *Myotis* (Chiroptera). Canadian Journal of Zoology, 57: 1271-1277.

Fenton, M.B., and R.M.R. Barclay. 1980. *Myotis lucifugus*. 142 Mammalian Species, pp. 1-8.

Findley, J.S., and C. Jones. 1967. Taxonomic relationships of bats of the species *Myotis fortidens, M, lucifugus*, and *M. occultus*. Journal of Mammalogy, 48: 429-444.

Frick, W.F., D.S. Reynolds, and T.H. Kunz. 2010a. Influence of climate and reproductive timing on demography of little brown *Myotis lucifugus*. Journal of Animal Ecology, 79: 128-136.

Frick, W.F., J.F. Pollock, A. Hicks, K. Langwig, D.S. Reynolds, G.G. Turner, C. Butchowski, T.H. Kunz. 2010b. A once common bat faces rapid extinction in the northeastern United States from a fungal pathogen. Science, 329:679-682.

Gargas, A. M.T. Trest, M. Christensen, T.J. Volk, D.S. Blehert. 2009. *Geomyces destructans* sp. nov. associated with bat White-Nose Syndrome. Mycotaxon, 108: 147-154.

Geiser, F. 2004. Metabolic rate and body temperature reduction during hibernation and daily torpor. Annual Review in Physiology, 66: 239-274.

Griffin, D. R. 1970. Migration and homing in bats. Pp. 233-264, In Biology of Bats, Vol. 2 (W. A. Wimsatt, ed.). Academic Press, New York, 477 pp.

Gruver, J., M. Sonnenburg, K. Bay and W. Erickson. 2009. Post-construction bat and bird fatality study at the Blue Sky Green Field Wind Energy Center, Fond du Lac County, Wisconsin: July 21, 2008 – October 31, 2008 and March 15, 2009 – June 4, 2009. Western EcoSystems Technology, Inc., Cheyenne, Wyoming, USA.

Hall, J.S., and F.J. Brenner. 1968. Summer netting of bats at a cave in Pennsylvania. Journal of Mammalogy, 49: 779-781.

Hanselmann, R., A. Rodriguez, and M. Lampo. 2004. Presence of an emerging pathogen of amphibians in introduced bullfrogs *Rana catesbeiana* in Venezuela. Biological Conservation, 120: 115-119.

Hayhoe, K., C. Wake, B. Anderson, X.-Z. Liang, E. Maurer, et al. 2008. Regional climate change projections for the northeastern USA. Mitigation and Adaptation Strategies for Global Change, 13: 425-436.

Hayhoe, K., C.P. Wake, T.G. Huntington, L. Luo, M.D. Schwartz, J. Sheffield, et al. 2007. Past and future changes in climate and hydrological indicators in the US Northeast. Climate Dynamics, 28: 381-407.

Hayssen, V., and T.H. Kunz. 1996. Allometry of litter mass in bats: comparisons with respect to maternal size, wing morphology, and phylogeny. Journal of Mammalogy, 77:476-490.

Henderson. L.E., L.J. Farrow, and H.G. Broders. 2009. Summer distribution and status of the bats of Prince Edward Island, Canada. Northeastern Naturalist, 16: 131-140.

Henry, M., D.W. Thomas, R. Vaudry, and M. Carrier. 2002. Foraging distances and home range of pregnant and lactating little brown bats (*Myotis lucifugus*). Journal of Mammalogy, 83: 767-774.

Hicks, A.C. 2008. White-nose syndrome: background and current status. www.caves.org/WNS/wns%203-30-08%20html/index.html.

Hilker, F.M. 2010. Population collapse to extinction: the catastrophic combination of parasitism and Allee effect. Journal of Biological Dynamics, 4: 86-101.

Hitchcock, H.B. 1949. Hibernation of bats in southeastern Ontario and adjacent Quebec. The Canadian Field-Naturalist, 63: 47-59.

Hitchcock, H.B. 1965. Twenty-three years of bat banding in Ontario and adjacent Quebec. The Canadien Field-Naturalist, 79: 4-14.

Horvath, G., G. Kriska, P. Malik, and B. Roberson. 2009. Polarized light pollution: a new kind of ecological photopollution. Frontiers in Ecology and the Environment, 7: 317-325.

Horvath, G., M. Blaho, A. Egri, G. Kriska, I. Seres, and B. Roberston. 2010. Reducing maladaptiveness of solar panels to polarotactic insects. Conservation Biology, doi: 10.1111/j.1523-1739.2010.01518.x.

Hughes, P.M., and J.M.V. Rayner. 1993. The flight of pipistrelle bats *Pipistrellus pipistrellus* during pregnancy and lactation. Journal of Zoology, London, 230: 541-555.

Humphrey, S. R., and J. B. Cope. 1976. Population ecology of the little brown bat, *Myotis lucifugus*, in Indiana and north-central Kentucky. Special Publications, American Society of Mammalogists, 4: 1-81.

Humphries, M.M., D.W. Thomas, and J.R. Speakman. 2002. Climate-mediated energetic constraints on the distribution of hibernating mammals. Nature, 418: 313-316.

Humphries, M.M., Speakman, J.R., and D.W. Thomas. 2006. Temperature, hibernation energetics, and the cave and continental distributions of little brown myotis. Pp. 23-37, In: (A. Zubaid, G.F. McCracken, and T.H. Kunz, eds.) Functional and Evolutionary Ecology of Bats. Oxford University Press, Oxford.

Huntington, T.G., A.D. Richardson, K.L. McGuire, and K. Hayhoe. 2009. Climate and hydrological changes in northeastern United States: recent trends and implications for forested and aquatic systems. Canadian Journal of Forest Research, 39: 199-212.

Jones, J. P.J. Doran, and R.T. Holmes. 2003. Climate and food synchronized regional forest bird abundances. Ecology, 84: 3024-3032.

Kalcounis, M.C., and R.M. Brigham. 1995. Intraspecific variation in wing loading affects habitat use by little brown bats (*Myotis lucifugus*). Canadian Journal of Zoology, 73: 89-95.

Kilpatrick, A.M., C.J. Briggs, and P. Daszak. 2009. The ecology and impact of chytridiomycosis: an emerging disease of amphibians. Trends in Ecology and Evolution 25: 109-118.

Krulin, G.S., and J.A. Sealander. 1972. Annual lipid cycle of the gray bat, *Myotis grisescens*. Comparative Biochemistry and Physiology, 42: 537-549.

Kunz, T. H., Arnett, E.B., Erickson, W.P., Hoar, A.R., Johnson, G.D., Larkin, R.P., Strickland, M.D., N. Thresher, R.W., & Tuttle, M.D. 2007. Ecological impacts of wind energy development on bats: questions, research needs, and hypotheses. Frontiers in Ecology and the Environment, 5: 315-324.

Kunz, T.H. 1988. Methods of assessing the availability of prey to insectivorous bats. Pp. 191-210. In: Ecological and Behavioral Methods for the Study of Bats (T.H. Kunz, ed.). Smithsonian Institution Press, Washington, D.C.

Kunz, T.H., and E.L.P. Anthony. 1982. Age estimation and post-natal growth in the little brown bat, *Myotis lucifugus*. Journal of Mammalogy, 63: 23-32.

Kunz, T.H., E.L.P. Anthony, and W.T. Rumage. 1977. Mortality of little brown bats following multiple pesticide applications. Journal of Wildlife Management, 41: 476-483.

Kunz, T.H., J.A. Wrazen, and C.D. Burnett. 1998. Changes in body mass and body composition in pre-hibernating little brown bats (*Myotis lucifugus*). Ecoscience, 5: 8-17.

Kurta, A., and T.H. Kunz. 1987. Size of bats at birth: an index of maternal investment during pregnancy. Pp. 79-106, In: Reproductive Energetics of Mammals (P.A. Racey and A. Loudon, eds.). Oxford University Press, London.

Kurta, A., G.P. Bell, K.A. Nagy and T.H. Kunz. 1989. Energetics of pregnancy and lactation in free-ranging little brown bats (*Myotis lucifugus*). Physiological Zoology, 62: 804-818.

Landesman, W.J., B.F. Allan, R.B. Langerhans, TM. Knight, and J.M. Chase. 2007. Inter-annual associations between precipitation and human incidence of West Nile Virus in the United States. Vector-Borne and Zoonotic Diseases, 7: 337-343.

Laussen, C.L., I. Delisle, R.M.R. Barclay, and C. Strobeck. 2008. Beyond mtDNA: nuclear gene flow suggests taxonomic oversplotting in the little brown bat (*Myotis lucifugus*). Canadian Journal of Zoology (London), 86: 700-713.

McCallum, H., D.M. Tomkins, M. Jones, S. Lachish, S. Marvenek, B. Lazenby, G. Hocking, J. Wiersma, and C.E. Hawkins. 2007. Distribution and impacts of Tasmanian Devil facial tumor disease. EcoHealth 4: 318-325.

McGuire, L.P., M.B. Fenton, and C.G. Guglielmo. 2009. Effect of age on energy storage during prehibernation swarming in little brown bats (*Myotis lucifugus*). Canadian Journal of Zoology, 87: 515-519.

Meteyer, C., E. Buckles, D. Blehert, A. Hicks, D. Green, V. Shearn-Bochsler, N. Thomas, A. Gargas, and M. Behr. 2009. Pathology criteria for confirming white-nose syndrome in bats. Journal of Veterinary Diagnostic Investigation, 21: 411-414.

Nebel, S., A. Mills, J.D. McCracken, and P. D. Taylor. 2010. Declines of aerial insectivores America follow a geographic gradient. *Avian Conservation and Ecology,* 5(2): 1. [online] URL: http://www.ace-eco.org/vol5/iss2/art1/

Neilson, A.L., and M.B. Fenton. 1994. Responses of little brown myotis to exclusion and bat houses. Wildlife Society Bulletin, 22: 8-14.

Peterson, A.T., N. Komar, O. Komar, A. Navarro-Siguenza, M.B. Robbins, and E. Martinez-Meyer. Priority contribution West Nile Virus in the New World: potential impacts on bird species. Bird Conservation International 14: 215-232.

Piaggio, A.J., E.W. Valdez, M.A. Bogan, and G.S. Spicer. 2002. Systematics of *Myotis occultus* (Chiroptera: Vespertillionidae) inferred from sequences of two mitochondrial genes. Journal of Mammalogy, 83: 386-395.

Polskey, G.R., and J.R. Sealander. 1979. Lipid deposition and withdrawal during hibernation in *Pipistrellus subflavus* (Chiroptera: Vespertilionidae). Southwestern Naturalist, 24: 71-78.

Powers, L.V., S.C. Kandarian, and T.H. Kunz. 1991. Ontogeny of flight in the little brown bat, *Myotis lucifugus*: behavior, morphology, and muscle histochemistry. Journal of Comparative Physiology, 168: 675-685.

Prendergast B.J., Freeman D.A., Zucker I. & Nelson R.J. 2002. Periodic arousal from hibernation is necessary for initiation of immune responses in ground squirrels. American Journal of Physiology: Regulatory, Integrative and Comparative Physiology, 282: R1054-R1062.

Puechmaille S, Verdeyroux P, Fuller H, Ar Gouilh M, Bekaert M, Teeling E. 2010. White-nose syndrome fungus (*Geomyces destructans*) in bat, France. Emerging Infectious Diseases, 16: 290-293.

Racey, P.A. 1973. Environmental factors affecting the length of gestation in heterothermic bats. Journal of Reproduction and Fertility 19, supplement: 175-189.

Reichard, J.D., and T.H. Kunz. 2009. White-Nose Syndrome inflicts lasting injuries to the wings of little brown myotis *(Myotis lucifugus)*, Acta Chiropterologica, 11: 457-464.

Reynolds, D. S. 1998. Variation in life-history traits in the little brown bat, *Myotis lucifugus* (Chiroptera: Vespertilionidae). Doctoral dissertation, Boston University, Boston, MA.

Rodhouse, T.J., S.A. Scott, P.C. Ormsbee, and J.M. Zinck. 2008. Field identification of *Myotis yumanensis* and *Myotis lucifugus*: a morphological evaluation. Western North American Naturalist, 68: 437-443.

Ross, J., and A.M. Tittensor. 1986. Influence of myxomatosis in regulating Rabbit numbers. Mammal Review, 16: 163-168.

Saunders, M.B., and R.M.R. Barclay. 1992. Ecomorphology of insectivorous bats: a test of predictions using two morphologically similar species. Ecology, 73: 1335-1345.

Schowalter, D.B. 1980. Swarming, reproduction, and early hibernation of *Myotis lucifugus* and *M. volans* in Alberta, Canada. Journal of Mammalogy, 61: 350-354.

Sillett, T.S., R.T. Holmes, and T.W. Sherry. 2000. Impacts of a global climate cycle on population dynamics of a migratory songbird. Science, 288: 2040-2042.

Syme, D.M., M.B. Fenton, and J. Zigouris. 2001. Roost and food supplies ameliorate the impact of bad summer on reproduction by the bat, *Myotis lucifugus* LeConte (Chiroptera: Vespertilionidae). Ecoscience, 8: 18-25.

Taylor, S.K., E.S. Williams, E.T. Thorne, K.W. Mills, D.I. Withers, and A.C. Pier. 1999. Causes of mortality of the Wyoming toad. Journal of Wildlife Diseases, 35: 49-57.

Thomas, D.W., and Geiser, F. 1997. Periodic arousals in hibernating mammals: is evaporative water loss involved? Functional Ecology, 11: 585-591.

Thomas, D.W., M.B. Fenton, and R.M.R. Barclay. 1979. Social behavior of the little brown bat, *Myotis lucifugus*. I Mating behavior. Behavioral Ecology and Sociobiology, 6: 129-136.

Twente, J.W., J. Twente, and V. Brack, Jr. 1985. The duration of the period of hibernation of three species of vespertilionid bats II. laboratory studies. Canadian Journal of Zoology, 63: 2955-2961.

van Zyll de Jong, C.G. 1985. Handbook of Canadian Mammals. 2. Bats. National Museums of Canada, Ottawa, 212 pp..

Wibbelt G., A. Kurth, D. Hellmann, M. Weishaar, A. Barlow, M. Veith, J. Prüger, T. Görföl, T. Grosche, F. Bontadina, U. Zöphel, H.-P. Seidl, P. Cryan, and D. Blehert. 2010. White-nose syndrome fungus (*Geomyces destructans*) in bats, Europe. Emerging Infectious Diseases, 16: 1237-1242.

Williams, C.B. 1951. Changes in insect populations in the field in relation to preceding weather conditions. Proceedings of the Royal Society B – Biological Sciences, 138: 130 156.

Williams, D.F., and J.S. Findley. 1979. Dimorphism in vespertilionid bats. American Midland Naturalist, 102: 113-126.

Wilson, D.E., and D. M. Reeder. 2005. Mammal Species of the World, 3rd Edition. The Johns Hopkins University Press, Baltimore.

Wilson, D.E., and S. Ruff. 1999. The Smithsonian Book of North American Mammals. The Smithsonian Institution Press, Washington, D.C.

Wimsatt, W.A. 1945. Notes on breeding behavior, pregnancy and paturition in some vespertilionid bats of the eastern United States. Journal of Mammalogy, 26: 23-33.

Wimsatt, W.A., and F.C. and Kallen. 1957. The unique maturation response of Graafian follicles of hibernating vespertilionid bats and the question of its significance. Anatomical Record, 129: 115-131.

X. ACKNOWLEDGMENTS

Principal researchers and authors of this status review are Dr. Jonathan D. Reichard and Dr. Thomas H. Kunz with Boston University's Center for Ecology and Conservation Biology, with assistance from Marc A. Bennett, an intern with the Wildlife Advocacy Project, and William S. Eubanks II, an attorney with the public interest law firm Meyer Glitzenstein & Crystal. The status review was made possible by a generous grant from Friends of Blackwater Canyon, and has been conducted in collaboration with Bat Conservation International and the Center for Biological Diversity.