2009

White-Nose Syndrome Threatens the Survival of Hibernating Bats in North America

U.S. Geological Survey

Fort Collins Science Center

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History of White-Nose Syndrome and Diseases in Hibernating Bats

During the winter of 2006/2007, an affliction of unknown origin dubbed "White-Nose Syndrome" (WNS) began devastating colonies of hibernating bats in a small area around Albany, New York. Colonies of hibernating bats were reduced 81-97% at the affected caves and mines that were surveyed. Since then, White-Nose Syndrome has been detected more than 700 kilometers (450 mi) away from the original site, and has infected bats in eight surrounding states. Most species of bats that hibernate in the region are now known to be affected and little brown bats (*Myotis lucifugus*), northern long-eared bats (*M. septentrionalis*), and federally listed (endangered) Indiana bats (*M. sodalis*) have been hit particularly hard. The sudden and widespread mortality associated with White-Nose Syndrome is unprecedented in hibernating bats, which differ from most other small mammals in that their survival strategy is to live **life in the slow lane**—their life history adaptations include high rates of survival and low fecundity, resulting in low potential for population growth. Most of the affected species are long lived (~5-15 years or more) and have only one offspring per year. Subsequently, bat numbers do not fluctuate widely over time, and populations of bats affected by White-Nose Syndrome will not recover quickly. Epizootic disease outbreaks have never been previously documented in hibernating bats.

An Emerging Disease of Hibernating Bats

White-Nose Syndrome was named for the visible presence of a white fungus around the muzzles, ears, and wing membranes of affected bats. Based upon what is known about typical fungal pathogens of typical mammals, this fungal growth was initially thought to be a secondary infection of bats with compromised immune systems. However, bats are anything but "typical" mammals (see below). Since then, a **previously unreported species of cold-loving fungus (*Geomyces* sp.) has been identified as a consistent pathogen among affected animals and sites**. This fungus, now widely considered to be the causal agent of WNS, thrives in the darkness, low temperatures (5-10ºC; 40-50ºF), and high levels of humidity (>90%) characteristic of bat hibernacula. Unlike typical fungi, this species of *Geomyces* cannot grow above 20°C (68ºF), and therefore appears to be exquisitely adapted to persist in caves and mines and to colonize the skin of hibernating bats. A consistent pattern of fungal skin penetration has been observed in over 90% of bats from the WNS-affected region that were submitted for disease investigation.

White-Nose Syndrome was first documented in a cave that is visited by tens of thousands of tourists each year, and the disease has since spread outward from that site. The focal area of origin and subsequent distribution of affected sites indicate that the newly identified fungus could be an invasive species with the capacity to spread rapidly among populations of hibernating bats. Researchers in Europe have long noticed similar fungal growth on the faces, ears, and wings of hibernating bats in Europe, but observed no associated mortality.

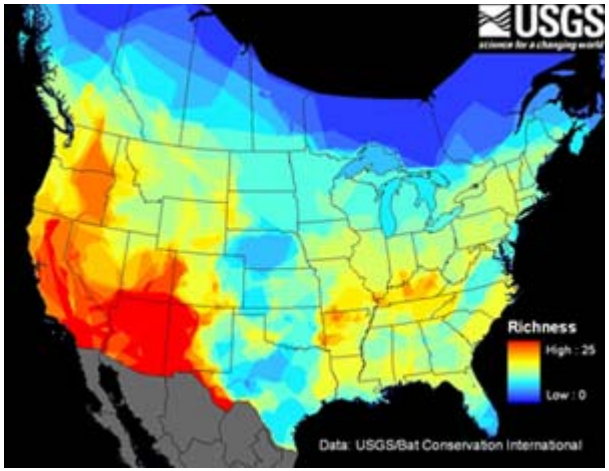
White-Nose Syndrome was named for the white fungus around the muzzles, ears, and wing membranes of affected bats. Photo: Meteyer et al. July 2009 [In Press]. JVDI Vol 21 No. 4.

Efforts are currently underway to assess whether there is any connection between fungi seen on bats in North America and Europe. An alternative hypothesis for the origin of White-Nose Syndrome is that this fungus was already present in North America, yet recently mutated to become an emerging disease.

What Makes Bats Susceptible to White-Nose Syndrome?

Pathologic findings thus far indicate that bats affected by White-Nose Syndrome prematurely run out of the stored body fat they rely on for winter survival. Species of bats occurring at the higher latitudes of the world rely on insects for food, which disappear from those temperate zones during winter. Most species of temperate zone bats survive the winter by building up fat reserves during autumn and then going to cold places to hibernate and wait out the winter insect shortage. During hibernation, a bat slows down its metabolism so that its body temperature remains just a few degrees above air temperature. This strategy allows a bat to consume very little fat over winter. Bats could easily last several months in this deep state of torpor, but they need to warm their bodies up a few times each winter and arouse from hibernation so that they can drink, urinate, mate, relocate, and probably induce their immune systems to catch up. These natural arousals from hibernation consume a lot of energy, and about 90% of a hibernating bat's winter fat is burned to fuel natural arousals. If anything increases the frequency or duration of such arousals during winter, the energy balance of a hibernating bat can quickly tip toward starvation. Chronic disturbance of hibernating bats is known to cause abnormal arousal patterns, and can result in high rates of winter mortality. For example, certain inappropriate research methods (e.g., poorly applied wing bands and frequent winter visitations) directed toward hibernating bats in the 1950's and 1960's caused chronic disturbance that led to high mortality and population declines in several U.S. bat species (**Ellison 2008**). Unlike typical microbial pathogens that cause collapse of internal organ systems, the *Geomyces* skin infection may act as a chronic disturbance during hibernation, and fungal-associated aberrant behaviors likely cause bats to consume critical fat reserves too quickly during winter. In addition to disrupting hibernation cycles, it is possible that affected bats expend their energy reserves trying to actively escape from hibernation sites infected with the cold-loving fungus. A common symptom observed at sites affected by White-Nose Syndrome is unusually large numbers of bats flying outside of hibernation caves and mines during the day.

The newly identified cold-loving fungus is now thought to be the primary causative agent of White-Nose Syndrome. Available evidence suggests the fungus establishes itself in the skin tissues of bats when their body temperatures are lowered during torpor (2-10ºC; 35-50ºF). Although life-threatening cutaneous fungal infections of this sort are rare in warm-blooded birds and mammals, **they occur more frequently** in "cold-blooded" animals (e.g., chytridiomycosis in amphibians, and crayfish plague). The cold-loving fungus seems to be infecting bats when they reduce their body temperatures during hibernation to levels characteristic of "cold-blooded" animals. Fungal infiltration of the wing membranes of bats may be particularly problematic. Wing membranes represent about 85% of a bat's total surface area and play a critical role in balancing complex physiological processes. Healthy wing membranes are vital to bats, as they help regulate body temperature, blood pressure, water balance, and gas exchange—not to mention the ability to fly and to feed. Although White-Nose Syndrome was named after the obvious sign of white noses on affected bats, bat



Hibernating species

	Species Name	Common Name
1	*Myotis auriculus*	Mexican long-eared bat
2	*Myotis austroriparius*	Southeastern bat
3	*Myotis californicus*	California bat
4	*Myotis ciliolabrum*	Western small-footed myotis
5	*Myotis evotis*	Western long-eared bat
6	*Myotis grisescens*	Gray bat
7	*Myotis keenii*	Keen's bat
8	*Myotis leibii*	Eastern small-footed bat
9	*Myotis lucifugus*	Little brown bat
10	*Myotis occultus*	Occult bat
11	*Myotis septentrionalis*	Northern long-eared bat
12	*Myotis sodalis*	Indiana bat

wings may indeed be the most vulnerable point of infection.

Because the newly identified fungus represents a potential **biological invasion** or emerging disease, with severe implications for hibernating bats in North America, it is important to focus on the history of its geographic distribution in the context of the distributions of affected species and those of federal concern that are potentially in harm's way.

Threat Posed by White-Nose Syndrome to Bat Diversity and Abundance in North America

Forty-five species of bats occur in the United States and Canada and bats represent more than 10% of mammalian species diversity in the region. The map at right shows bat species richness in the continental United States and Canada. Warmer colors represent higher species richness, cooler colors represent fewer species.

More than half of the species of insectivorous bats that occur in the U.S. rely on hibernation as a primary strategy for surviving the winter when insect prey is not available. The table at right lists all 45 species of bats known to occur in the continental United States and Canada. Species in the upper list are those that in most areas rely on hibernation to survive the winter. Species in the lower list are those that generally do not rely on hibernation as a winter survival strategy. Those highlighted in yellow text are species currently known to be affected by White-Nose Syndrome.

The emergence and spread of a pathogenic fungus that infects hibernating bats has the potential to undermine the basic survival strategy of more than half the bat species in the U.S. and all species of bats that occur in the higher latitudes of North America. With the exception of 4 species of **migratory tree bats**, the other 18 bat species that occur above 40°N in North America (roughly a line running from the top of California across Nebraska to Virginia) hibernate to survive the winter.

The shaded red areas on the map below represent the overlapping distributions of 19 species of bats occurring in the U.S. that do not rely on hibernation as a strategy for surviving the winter. The blue shaded areas of the map below represent the overlapping distributions of 25 species of bats occurring in the U.S. that rely on hibernation to survive the winter. The distributions of four species of **migratory tree bats** are not shown.

13	*Myotis thysanodes*	Fringed bat
14	*Myotis velifer*	Cave bat
15	*Myotis volans*	Long-legged bat
16	*Myotis yumanensis*	Yuma bat
17	*Nycticeius humeralis*	Evening bat
18	*Parastrellus hesperus*	Canyon bat
19	*Perimyotis subflavus*	Tricolored bat
20	*Corynorhinus townsendii*	Townsend's big-eared bat
21	*Corynorhinus rafinesquii*	Rafinesque's big-eared bat
22	*Eptesicus fuscus*	Big brown bat
23	*Antrozous pallidus*	Pallid bat
24	*Euderma maculatum*	Spotted bat
25	*Idionycteris phyllotis*	Allen's big-eared bat

Long-distance Migrants / Non-hibernating species

	Species Name	Common Name
1	*Mormoops megalophylla*	Ghost-faced bat
2	*Choeronycteris mexicana*	Mexican long-tongued bat
3	*Leptonycteris nivalis*	Greater long-nosed bat

Figure 1: Maps illustrating the overlapping ranges of non-hibernating (left) and hibernating (right) species of U.S. bats.

Among the 25 species of bats that hibernate across North America, four species and subspecies are federally listed as endangered and an additional 13 are federal species of concern (former Category 2 candidates for listing under the U.S. Endangered Species Act). All four endangered species and subspecies of hibernating bats in the U.S., which rely on undisturbed caves or mines for successful hibernation, are at risk from White-Nose Syndrome. Two of these species are currently within the affected area, and the remaining two may be affected in the next few years if not sooner.

The map below shows the distribution of endangered species of hibernating bats (shaded areas) in relation to the expanding distribution of White-Nose Syndrome (yellow lines). Endangered species include Ozark big-eared bats (*Corynorhinus townsendii ingens*), Virginia big-eared bats (*C. t. virginianus*), Indiana bats (*M. sodalis*), and gray bats (*M. grisescens*). Areas outlined in yellow were those known to be affected by White-Nose Syndrome during the winters of 2006/2007 (small circle), 2007/2008 (larger circle), and 2008/early 2009 (dashed line). For updated map of sites affected by WNS see **http://www.fws.gov/northeast/white_nose.html**.

4	*Leptonycteris yerbabuenae*	Lesser long-nosed bat
5	*Macrotus californicus*	California leaf-nosed bat
6	*Lasionycteris noctivagans*	Silver-haired bat
7	*Lasiurus blossevillii*	Western red bat
8	*Lasiurus borealis*	Eastern red bat
9	*Lasiurus cinereus*	Hoary bat
10	*Lasiurus ega*	Southern yellow bat
11	*Lasiurus intermedius*	Northern yellow bat
12	*Lasiurus seminolus*	Seminole bat
13	*Lasiurus xanthinus*	Western yellow bat
14	*Eumops floridanus*	Florida bonneted bat
15	*Eumops perotis*	Greater mastiff bat
16	*Eumops underwoodi*	Underwood's mastiff bat
17	*Molossus molossus*	Pallas' mastiff bat
18	*Nyctinomops femorosaccus*	Pocketed free-tailed bat
19	*Nyctinomops macrotis*	Big free-tailed bat
20	*Tadarida brasiliensis*	Brazilian free-tailed bat

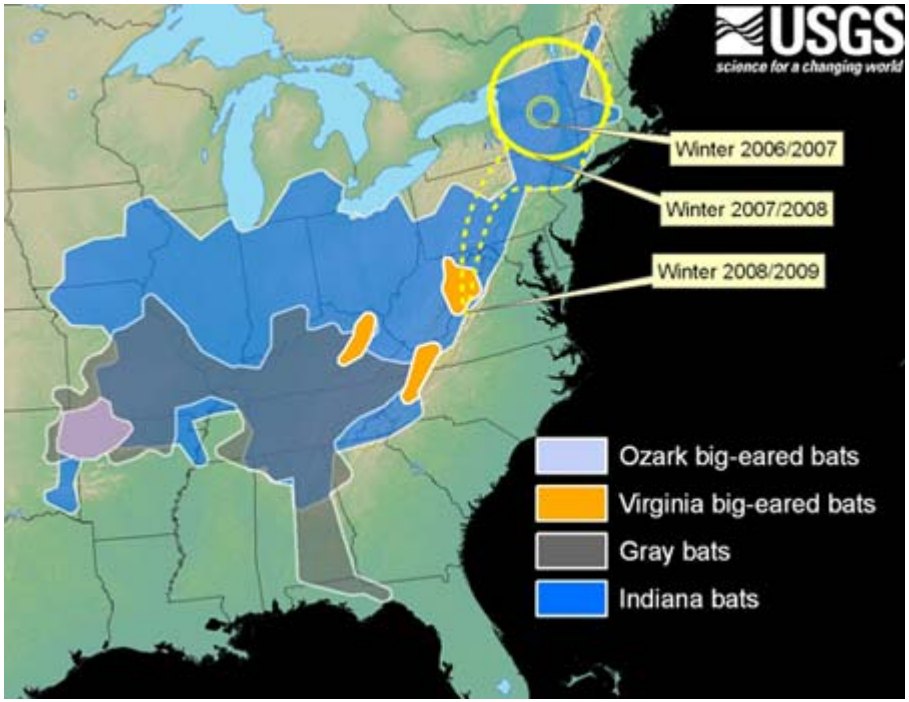


Figure 2: Map illustrating the ranges of endangered species of hibernating bats in the U.S. and the spreading distribution of White-nose syndrome (WNS).

Although the true potential for this fungus to spread is unknown, the possibility of it undermining the ubiquitous survival strategy of bats at higher latitudes has enormous implications. We are just beginning to appreciate the roles that bats play in North American ecosystems, and it is clear that threats like White-Nose Syndrome have the potential to influence ecosystem function in ways that we currently do not understand.

Since White-Nose Syndrome emerged during the winter of 2006/2007, a diverse group of scientists, resource managers, and conservation groups have worked diligently to establish its cause. Efforts are now being directed toward developing solutions to the WNS crisis and minimizing its impact on populations of hibernating bats in North America.

USGS scientists at the **National Wildlife Health Center** and **Fort Collins Science Center** are supporting the research needs of the **U.S. Fish & Wildlife Service** and other federal and state agencies as they respond to the developing situation.

Related Resources

Research

- **Ecological Investigations of White-Nose Syndrome in Bats**

- Causes and Consequences of Bat Fatalities at Wind Turbines
- Conservation Studies of Long-Nosed Bats in New Mexico
- Ecology of Virus Transmission in Commensal Bats
- Bat Species of Concern: An Ecological Synthesis for Resource Managers
- USGS National Wildlife Health Center: White-Nose Syndrome (WNS)
- U.S. Fish and Wildlife Service, Northeast Region: White-Nose Syndrome in Bats: Something Is Killing Our Bats
- American Museum of Natural History, Science Bulletins, Bio Bulletin: Bat Sickness Spreads to New States

Headlines

- New Web Site on White-Nose Syndrome in Bats
- FORT Bat Expert to Present Research at International Symposium
- USGS Bat Expert Covers Two Bases at Upcoming Conference

Publications / Products

- USGS Bat Population Database
- Overview of issues related to bats and wind energy: Web version of presentation to the Wind Turbine Guidelines Advisory Committee Technical Workshop & Federal Advisory Committee Meeting, Washington, D.C., 26 February, 2008
- Autumn migration and selection of rock crevices as hibernacula by big brown bats in Colorado
- Existing data on colonies of bats in the United States: summary and analysis of the U.S. Geological Survey's Bat Population Database
- Monitoring trends in bat populations of the United States and territories: status of the science and recommendations for the future

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