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WHITE-NOSE SYNDROME IN BATS

Biologists strive to understand and contain the invasive fungal infection affecting hibernating bats in the Northeast

ON THE COVER

What's wrong with this picture? The white patches on the nose and wing membranes of this eastern small-footed bat (*Myotis leibii*) are an invasive fungal growth affecting bats in the northeastern United States and Canada. Discovered just three years ago, white-nose syndrome is spreading rapidly from its discovery site in New York, through 11 additional states and two Canadian provinces. In April of this year bats affected by the fungus were discovered at Great Smoky Mountains National Park. The article on page 20 will introduce you to what is known about this troubling disease and how to help prevent its spread.

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State of Science

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White-nose syndrome in bats:

A primer for resource managers

By Kevin T. Castle and Paul M. Cryan

Abstract

White-nose syndrome emerged as a devastating new disease of North American hibernating bats over the past four winters. The disease has spread more than 1,600 kilometers (1,000 mi) since it was first observed in a small area of upstate New York, and has affected six species of bats in the caves and mines they rely on for winter survival. A newly discovered, cold-loving fungus (*Geomyces destructans*) causes the characteristic skin infection of white-nose syndrome and can infect presumably healthy bats when they hibernate. Although clear links between skin infection by *G. destructans* and death have not yet been established, the fungus is the most plausible cause of the disease. Thousands of caves and mines are administered by the National Park Service. Although bats testing positive for white-nose syndrome have been detected only at two sites in the National Park System thus far, the National Park Service (NPS) has been preparing for the spread and effects of white-nose syndrome through a proactive national program of response coordination, research support and interpretation, and education. National park areas across the nation are uniquely situated to help understand white-nose syndrome and its ecosystem impacts, and assist in the conservation and recovery of affected bat species.

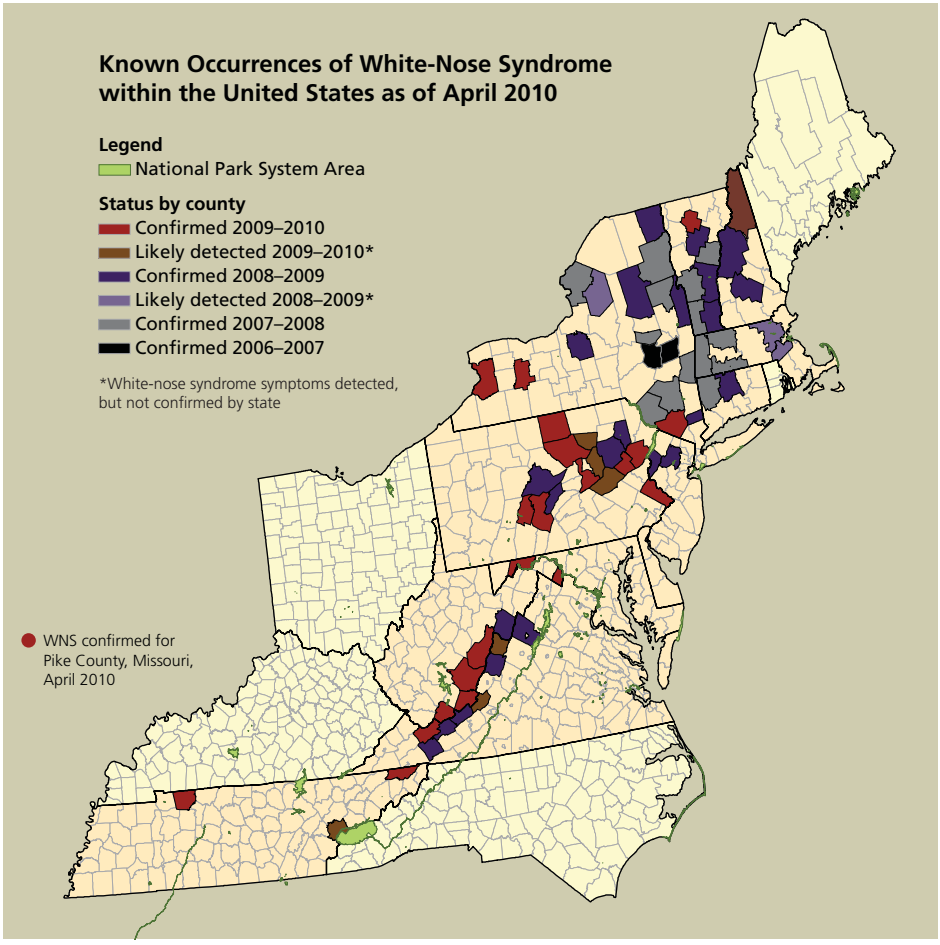
Key words

bats, caves, conservation, disease, federal lands, fungus, management, mines, white-nose syndrome, wildlife disease

WHITE-NOSE SYNDROME (WNS) is a disease responsible for unprecedented mortality in hibernating bats in the eastern United States and Canada. This previously unknown disease has spread very rapidly since its discovery in January 2007, and may pose a considerable threat to hibernating bats throughout North America. As white-nose syndrome spreads, the challenges for understanding and managing the disease are increasing.

History

White-nose syndrome was first observed in four caves near Albany, New York, in the winter of 2006–2007. Before the onset of the disease, decades of winter surveys for hibernating bats that occur in New York indicated healthy and increasing populations (Hicks and Novak 2002). Since 2007, white-nose syndrome has spread more than 1,600 kilometers (1,000 mi) through 11 additional states and devas-



CAL BUTCHKOSKI, PENNSYLVANIA GAME COMMISSION, MODIFIED BY DANEILLE LAGANA AND SCOTT RATCHFORD, NATIONAL PARK SERVICE

Figure 1. Map of the northeastern United States showing the status of white-nose syndrome occurrence in bats by county.

Table 1. Hibernating cave bats susceptible to white-nose syndrome

Common Name	Scientific Name
Little brown bat	*Myotis lucifugus*
Northern long-eared bat	*Myotis septentrionalis*
Indiana bat	*Myotis sodalis*
Eastern small-footed bat	*Myotis leibii*
Tricolored bat	*Perimyotis subflavus*
Big brown bat	*Eptesicus fuscus*

tated populations of bats in its path. As of mid-April 2010, white-nose syndrome has been confirmed as far west as St. Louis, Missouri. Overall declines of hibernating colonies at the most closely monitored New York sites reached 75% within two to three years of initial detection (Blehert et al. 2009). As of winter 2009–2010, white-nose syndrome had been detected in six of the seven species of hibernating bats that occur in the affected region (fig. 1). Species affected to date are listed in table 1.

The disease appears primarily to affect insectivorous bats while they are hibernating, and hibernators comprise the majority of the 45 species of bats that occur in the United States. Most bats living in cold temperate zones survive the harsh conditions of winter by moving to cold places,

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Figure 2. A close-up of a little brown bat (*Myotis lucifugus*) reveals the white fungal growth associated with white-nose syndrome on its muzzle (facing page) and on its wing and tail membrane (above), New York, October 2008.

where they lower their body temperature to save energy and metabolize stored body fat until insect food becomes available again (Ransome 1990). These flying insect predators are long-lived (approximately 5–15 years or more) and reproduce slowly. Like other top mammalian predators, such as polar bears and mountain lions, numbers of hibernating bats do not fluctuate widely over time, and populations affected by white-nose syndrome will likely take a very long time to recover.

White-nose syndrome was initially named "fuzzy muzzle" by some biologists, for the visible presence of a white fungal growth around the muzzles, ears, and wing membranes of affected bats (fig. 2). In summer 2009, scientists identified a previously unknown species of cold-loving fungus (*Geomyces destructans*) as a consistent pathogen causing skin infection in bats at affected sites (Gargas et al. 2009). This fungus thrives in low temperatures (5–14°C; 40–55°F) and high levels of humidity (>90%), conditions that are characteristic of both the bodies of hibernating bats and the caves and mines in which they hibernate (fig. 3, next page). Chronic disturbance of hibernating bats can cause high rates of winter mortality through loss of fat and possibly water, and effects associated with skin infection by *G. destructans* may also cause bats to consume critical fat and water reserves too

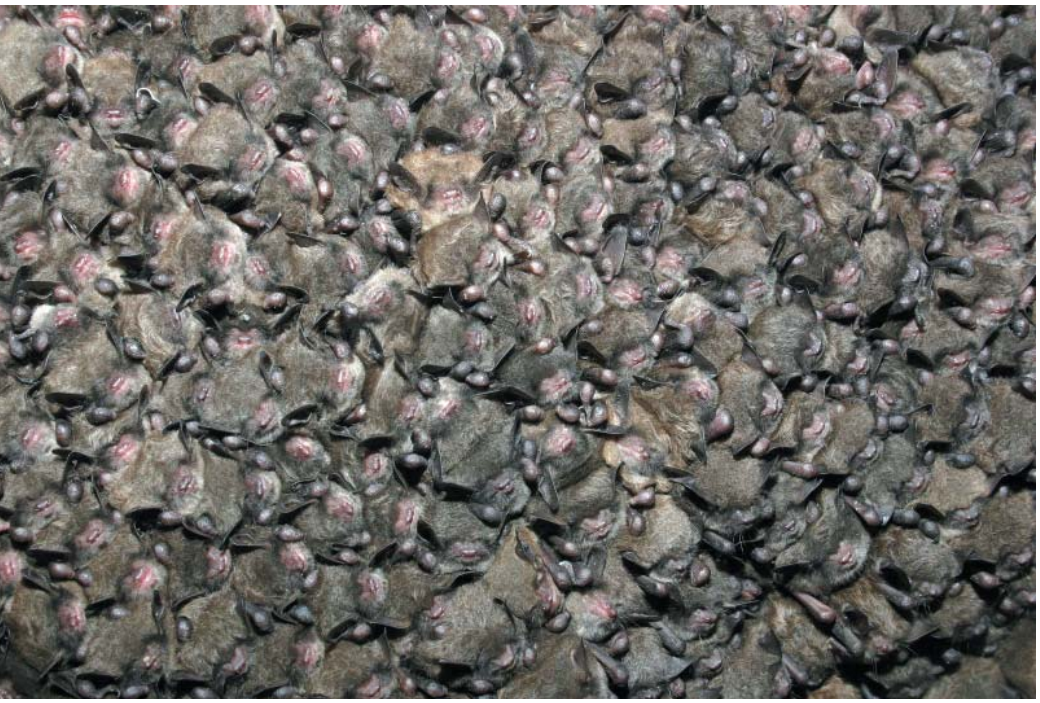

Figure 3. Hibernating Indiana bats (*Myotis sodalis*) form a cluster in a New York cave. The density of bats, which may be as high as 300 individuals per square foot, could enhance the spread of white-nose syndrome. ALAN HICKS, NEW YORK DEPARTMENT OF ENVIRONMENTAL CONSERVATION

quickly during winter. Aberrant behaviors observed at sites affected by white-nose syndrome can include (1) large numbers of bats moving within hibernacula to roosts near entrances or to unusually cold areas; (2) large numbers of bats flying during the day outside of hibernacula in midwinter; (3) general unresponsiveness to human disturbance; and (4) large numbers of fatalities, either inside hibernacula or near their entrances. Not all of these behaviors may occur at affected hibernacula; this is particularly true of mortality early in the disease onset. Skin infection by *G. destructans* is a plausible primary cause of mortality associated with the disease. However, the exact processes by which skin infection leads to death remain undetermined and it is unclear whether other underlying conditions contribute to mortality (Meteyer et al. 2009).

One of the greatest mysteries surrounding white-nose syndrome was its rapid appearance. Biologists in North America had never reported white fungus on the muzzles of living bats in winter, yet reports from European scientists indicated that similar fungal growth had been seen on hibernating European bats since the mid-1980s. However, there are no reports of bat mortality associated with such fungal infections in Europe. A recent publication compared small portions of the genome of *G. destructans* from North America with fungal samples recovered from a French bat (*Myotis myotis*), and found that the two were identical (Puechmaille et al. 2010). Additional genetic research is being conducted in Europe and the United States to further compare these fungal isolates, to determine if and when *G. destructans* may have spread from Europe to North America, and to determine why European bats seem less prone to mortality. Bats do not naturally migrate between Europe and North America, so if *G. destructans* was recently introduced to the United States, it is highly unlikely that it arrived here on the wings of a bat without human assistance.

Spread of the disease

Bats undoubtedly play a major role in spreading the disease from one area to another through local movements and long-distance migration. Laboratory experiments have shown that *G. destructans* can be transmitted among diseased and presumably healthy bats through physical contact (USGS 2009). Studies are ongoing to determine whether *G. destructans* persists in cave or mine environments and infects bats that subsequently come into contact with it, although preliminary evidence suggests sites can remain infectious. Humans may also unwittingly transmit the fungus from one place to another. There is circumstantial evidence to support the potential for this mode of transmission among popular recreational caving sites (USGS 2009). The fact that the same fungus exists on two continents provides compelling evidence of long-distance, human-assisted spread.

NPS-protected resources at stake?

Caves

Nearly 4,000 caves are administered by the National Park Service in roughly 85 different units of the National Park System. In addition, approximately 126 park units have mines, which total almost 3,100 in number. Among the most well-known parks with caves are Mammoth Cave and Carlsbad Caverns national parks and Jewel Cave and Timpanogos Cave national monuments. Mammoth and Jewel are the world's two longest caves, with surveyed lengths of 580 kilometers (360 mi) and 241 kilometers (150 mi), respectively. Although some caves exhibit extraordinary geologic, hydrologic, and biologic features, all caves in the National Park System are classified as "significant" by the Federal Cave Resources Protection Act. Mines are not generally afforded the same level of resource protection, although some contain significant bat populations. Many NPS-administered caves and mines provide important refuge for bats by serving as winter hibernacula or summer maternity roosts.

Bats do not naturally migrate between Europe and North America, so if* G. destructans *was recently introduced to the United States, it is highly unlikely that it arrived here on the wings of a bat without human assistance.

Figure 4. Biologists from the National Park Service and U.S. Geological Survey have installed remotely triggered infrared cameras in a cave at Cumberland Gap National Historical Park in Kentucky, to help document and investigate how white-nose syndrome might lead to bat mortality.

NPS/KEVIN CASTLE

Throughout the National Park System, caves and mines also provide habitat for rare or unique life-forms in addition to bats.

Bats

More than 40 bat species are found in the National Park System in the contiguous 48 states. A majority are insectivorous, cave-dwelling species that hibernate and are, therefore, susceptible to white-nose syndrome. A number of national park areas (e.g., Mammoth Cave, Great Smoky Mountains, Cumberland Gap) contain hibernacula or maternity colonies of one or more of the four hibernating bat species and subspecies that are federally listed as threatened or endangered (T&E species) under the U.S. Endangered Species Act. Those and other parks are also home to large colonies of non-T&E species that could be severely affected by white-nose syndrome. In the temperate zones of North America, bats are the major, and sometimes only, predators of night-flying insects. Hibernating bats have always been an important part of both natural and human-modified ecosystems in the United States and certainly have beneficial effects on our lives. For example, many of the crops grown in the United States and Canada are likely protected from night-flying insect pests by bats (e.g., Cleveland et al. 2009). White-nose syndrome has the potential to alter these "secret alliances" in ways that are difficult to predict.

Visitors

Each year approximately 1.7 million recreational visits are recorded at parks such as Mammoth Cave, Carlsbad Caverns, Jewel Cave, Timpanogos Cave, and Wind Cave, where cave resources are primary features. Roughly 2.4 million visits are recorded annually at Cumberland Gap National Historical Park, Great Basin National Park, and Ozark National Scenic Riverways, where caves are important but not primary features. If caves were closed year-round to all visitation because of the impacts of white-nose syndrome on bats inhabiting those caves, visitor enjoyment of those areas would be greatly diminished. In addition, the economic impacts on parks and gateway communities could be severe. The high number of visitors to our national parks gives the National Park Service an unmatched opportunity to educate people about white-nose syndrome and to ask for their assistance in controlling the spread of this disease.

NPS roles

The NPS Wildlife Management and Health Program (Biological Resource Management Division) leads an NPS white-nose syndrome working group made up of cave and bat ecologists, regional biologists, and a park superintendent. The primary objectives of the working group are to disseminate information among parks and regions and to help interpret general management recommendations made by non-NPS agencies in light of NPS policies. The Wildlife Management and Health Program remains involved in interagency working groups, including a team developing national guidance on white-nose syndrome.

In February 2009, three dead bats found near an abandoned mine at Delaware Water Gap National Recreation Area in Pennsylvania were submitted for WNS testing and were positive for *G. destructans* and white-nose syndrome. In early April 2010, bats from Great Smoky Mountains National Park tested positive for the fungus. Despite the proximity of a number of additional park units to WNS-positive hibernacula (see fig. 1), Delaware Water Gap and Great Smoky Mountains are the only sites in the National Park System with bats that have tested positive for white-nose syndrome. Active surveillance for endangered species in national parks such as Mammoth Cave is typically conducted biannually, and additional surveys have been conducted at national parks by federal and state biologists to monitor the spread of white-nose syndrome. As of February 2010, surveys at Mammoth Cave have revealed normal bat numbers and activity levels but no indication of white-nose syndrome.

Research

Many national park area caves with significant bat populations or other significant resources are already off-limits to research, except to those who have proper permits. In response to the WNS threat, many more caves in national park areas have been closed. The National Park Service is assisting the investigation of white-nose syndrome by helping to identify knowledge gaps and by supporting research to better understand the disease. There is a largely unmet need for research to determine basic information about white-nose syndrome before effective management strategies can be invoked, including routes and rates of transmission, biology of *G. destructans*, pathogenesis, control methods, bat species susceptibility or resistance, and effects on other animal species. An overarching NPS goal is to ensure that scientists working in national parks engage in research and management activities that do not make things worse for the bats or the ecosystems of which they are an integral part. To minimize the potential for humans to introduce white-nose syndrome into bat caves, a number of parks have obtained park-specific caving and bat-capturing equipment or have purchased washing machines and dryers so that researchers and others with a need to enter caves or handle bats do not risk spreading the disease. Scientists from the U.S. Geological Survey and the National Park Service are collaborating on a project at Cumberland Gap in Kentucky to monitor hibernating bats using remotely triggered infrared cameras so bat disturbance is minimized (fig. 4). Although white-nose syndrome has not yet reached this park, the objective of the camera project is to document normal bat behaviors during hibernation so that aberrant behaviors that occur in the presence of the disease can be evaluated.

Education

National park staffs have an excellent opportunity to educate millions of people about white-nose syndrome because of the large number of visitors they contact. A number of national park areas have developed education materials, including interactive Internet pages, brochures, bulletin boards, and "live" information booths staffed by NPS interpretive and education personnel. Mammoth Cave, for example, uses all of the education materials mentioned and has combined a visitor footwear decontamination area with a WNS educational booth.

Recovery and conservation

A critical role for the National Park Service is to minimize disturbance of bats that hibernate or roost on its lands. It can be difficult to balance the need for information gained by directly observing bats with the need to minimize stress when bats are weakened or debilitated by disease. Caves and other areas in national parks where bats congregate may ultimately serve as refuges for bats that survive white-nose syndrome, because the National Park Service has a mandate to protect resources on its lands and can limit access to significant hibernacula and roosts. White-nose syndrome may render historical hibernacula and roosts unsuitable or unappealing for bat use and bats may begin to use other natural or artificial sites that have not been used before, including those on lands administered by the National Park Service.

National leadership role

National Park Service personnel have been involved with national WNS coordination efforts since March 2008. Since then, NPS wildlife veterinarians and cave and bat biologists have regularly attended national and regional WNS meetings. In autumn 2009 a multiagency effort to formalize a national plan for WNS investigation and management was initiated. Wildlife veterinarians with the National Park Service have an active role on the plan steering committee and the writing team.

What should national park staffs do?

In response to white-nose syndrome, the U.S. Fish and Wildlife Service and other federal agencies have recommended cave closures, decontamination procedures, and other management actions if the disease continues to spread. On 17 April 2009 the National Park Service issued guidance concerning white-nose syndrome in the national parks to help clarify the NPS position. The primary message of that memorandum and subsequent recommendations from the NPS Washington Office is that field-based staffs continue to make WNS management decisions based on the best science available and in accordance with the NPS mission, policies, and park enabling legislation. Recommendations include:

- Restrict access to caves serving as bat hibernacula or maternity roosts.
- In unaffected areas, ensure that gear entering caves has not been used in affected areas.
- Ensure proper decontamination of gear that is moved within affected areas.
- Review all cave-use permit requests, and approve only requests for scientific or educational purposes whose benefits outweigh the risk of potentially spreading white-nose syndrome.
- Collect and submit samples of dead bats to the appropriate diagnostic laboratories, following standard carcass submission procedures and safe work practices (found on the InsideNPS intranet site).
- Although there does not appear to be a direct human health risk related to white-nose syndrome, the NPS

Office of Public Health recommends that people handling bats use safe work practices and personal protective equipment to minimize exposure to, and spread of, infectious or toxic agents.

- Participate in public awareness and education to inform park visitors about white-nose syndrome and its threat to bat conservation.

Conclusions

White nose syndrome is an unprecedented danger to bat populations in the eastern United States and possibly to bat populations throughout North America. More than half of the 45 species of bats that occur in the United States rely entirely on hibernation as a winter survival strategy, when temperatures drop below freezing and insect prey is not available. Although the potential for *G. destructans* to continue to spread through hibernating bat populations is unknown, the implications of it undermining the survival strategy of so many bat species are enormous. We are just beginning to appreciate the important roles bats play as nocturnal flying predators in North American ecosystems. The unprecedented loss of bat populations in the wake of white-nose syndrome has the potential to alter the function of ecosystems and adversely impact the global economy through cascading effects, such as when crop- or forest-damaging insects typically eaten by bats are left unchecked. As with any wildlife disease that causes wide-scale mortality, understanding and managing white-nose syndrome will not be an easy task and the veterinary creed "first do no harm" must be followed. White-nose syndrome does not respect state or regional borders. National park areas across the nation are uniquely situated to help understand white-nose syndrome and its ecosystem impacts, and to assist with the conservation and recovery of affected bat species.

The National Park Service will be broadcasting a Service-wide white-nose syndrome Web-based seminar on Wednesday, 9 June 2010. All NPS personnel are invited to participate.

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Links for more information

NPS Wildlife Health Program

http://www1.nrintra.nps.gov/BRMD/Wildlife_Health_Management/Wildlife_Health/White_Nose_Syndrome.cfm

U.S. Fish and Wildlife Service

http://www.fws.gov/northeast/white_nose.html

USGS Fort Collins Science Center

http://www.fort.usgs.gov/WNS/

USGS National Wildlife Health Center

http://www.nwhc.usgs.gov/disease_information/white-nose_syndrome/index.jsp

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