REIGN OF THE RED QUEEN

the future of bats hangs in the balance

by J. JUDSON WYNNE

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HIBERNATING TOWNSEND'S BIG-EARED BATS (*CORYNORHINUS TOWNSENDII*) FROM A CAVE ON GRAND CANYON-PARASHANT NATIONAL MONUMENT, NORTHWESTERN ARIZONA. PHOTOGRAPH BY J. JUDSON WYNNE.

Maligned in old wives' tales for "getting in your hair" and wrongly considered a primary vector for rabies, bats are in fact among the most important contributors to Earth's ecosystems. They are a keystone species in cave ecosystems, their guano adding allochthonous nutrients to an otherwise energy-limited environment; they are important seed dispersers, particularly in tropical forests; and they provide critical ecological services to humankind. In this latter role, insectivorous bats are one of the most overlooked yet important animals. In the United States alone, bats provide between $4 and $50 billion annually in pest-control-related ecological services to agriculture. Other bat species are important pollinators for agave—the plant used for making tequila.

Yet, North American bat colonies are facing a crisis with the westward advance of white-nose syndrome (WNS), a disease responsible for the deaths of nearly seven million bats since it was first detected in Howe Cave, near Albany, New York, during the winter of 2006–2007. Since then, WNS has been confirmed in 23 states and 5 Canadian provinces.

WNS is a disease caused by the cold-loving fungus, *Pseudogymnoascus destructans*, which infects the skin of the ears, snout, and wings of hibernating bats. During hibernation, a bat's immune response is in a suppressed state as are other metabolic functions, enabling the fungus to spread relatively unchecked. When fully expressed, WNS often presents as a prominent white fungal growth. The fungal hyphae penetrate deeply into the connective tissue and cause severe damage.

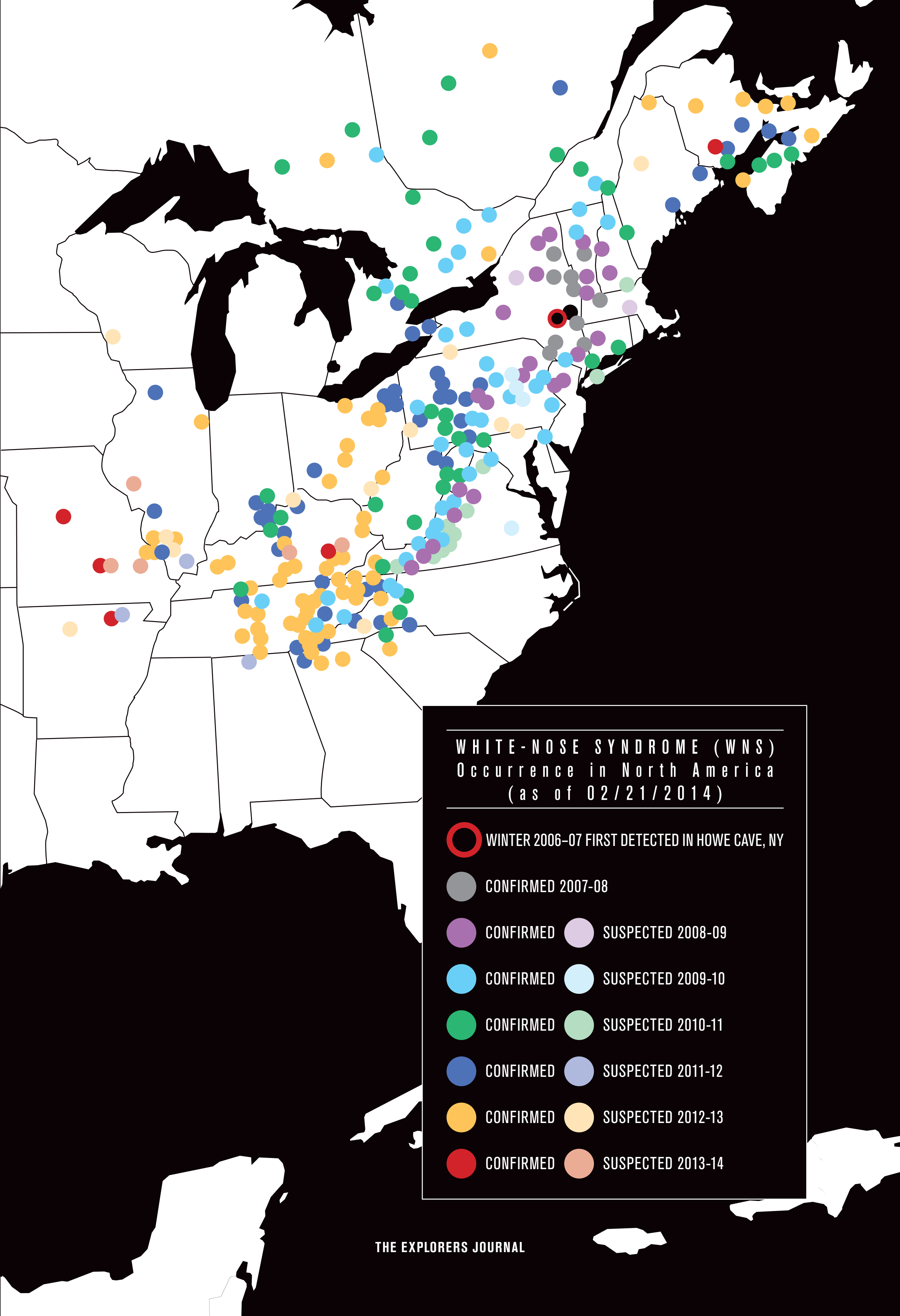
Researchers believe this epizootic did not originate in New York but rather was transported to North America from Europe, where interestingly, *P. destructans* and hibernating bats seem to coexist. Hibernating bats with signs of white fungal growth—confirmed as *P. destructans*—from some 12 European countries have been examined thus far, but there is no evidence of recent mass mortalities.

This bat-fungus interaction may also be described as antagonistic coevolution. This game of one-upmanship between bats and fungus can be explained by the Red Queen hypothesis, which was inspired by a passage in Lewis Carroll's *Through the Looking Glass,* in which the Red Queen tells Alice "… it takes all the running you can do, to keep in the same place."

All organisms in the natural world must continuously adapt and evolve, not only for the sake of reproductive success, but for survival against constantly evolving competitors, predators, and parasites in a continuously changing environment. When European bats were first exposed to *P. destructans*, it is possible they suffered similar population declines as have been observed in North America. Like the exhausted young Alice, European bats likely "ran" as fast as they could to maintain their place (i.e., persistence in the natural world). Over time, European bats developed immunity to the fungus and their populations rebounded.

Today, North American bats are faced with the same ecological challenge. We do not know whether the fungus requires bats to survive (i.e., dispersal to other caves or completion of its life cycle). Current research indicates that the fungus can persist in caves without bats. Regardless, it seems, at least at the moment, that European bats have the upper hand against the fungus, while the fungus maintains an advantage over North American bats.

In North America, not all bats hibernate, but those that do generally hibernate for three to four months—from mid- to late November through early March. During this time, these animals have limited stored energy (fat reserves), enabling them to get through hibernation if they curtail activity. Essentially, bats have a hibernation "budget." Although they periodically arouse from hibernation to switch roost locations within a roost, move to another roost entirely, and seek water and/or forage when conditions outside the cave are favorable, these activities typically fall within their budget. WNS forces bats to overspend. Infected bats may arouse more often and may remain active


WHITE-NOSE SYNDROME (WNS)
Occurrence in North America
(as of 02/21/2014)
WINTER 2006–07 FIRST DETECTED IN HOWE CAVE, NY
CONFIRMED 2007-08
CONFIRMED SUSPECTED 2008-09
CONFIRMED SUSPECTED 2009-10
CONFIRMED SUSPECTED 2010-11
CONFIRMED SUSPECTED 2011-12
CONFIRMED SUSPECTED 2012-13
CONFIRMED SUSPECTED 2013-14

for longer periods of time, further reducing their precious fat reserves. These animals may ultimately leave their winter roost in search of food and water when surface conditions are unfavorable (i.e., snow-covered). Other aberrant behaviors associated with this disease may include diurnal flight activity outside of the hibernation sites (hibernacula), collisions with large stationary objects, and increased concentrations of bats in hibernacula entrances and other exposed areas during winter. Bats who succumb to WNS often die of starvation and dehydration, predation, or exposure.

It is unlikely that species of bats affected by WNS will recover quickly because most are long-lived and have only one pup per year. Consequently, even in the absence of disease, bat populations do not fluctuate widely over time. Many North American bat species, which can be sensitive to human disturbance, are already threatened by climate change and habitat loss. The added threat of WNS further complicates an already uncertain future for North American bat populations.

There may be hope for bat populations in the American Southwest, in particular, those in Arizona. With 28 bats species, Arizona is the second-most bat-diverse state in America. Arizona bats fill a variety of ecological niches ranging in elevation from deserts to montane forests; they also have disparate habitat and foraging requirements.

Hibernating bats, such as the Townsend's big-eared bat (*Corynorhinus townsendii*) and most myotine species (Myotis spp.) are among the highest at risk as conspecific and congener populations have already dramatically declined in eastern North America due to WNS. The California leaf-nosed bat (*Macrotus californicus)*, on the other hand, is homeothermic and thus remains active within the southwestern region throughout winter. As a result, it may not be at risk from WNS. Other species that may escape the disease are the Mexican free-tailed bat (*Tadarida brasiliensis*), Mexican long-tongued bat (*Choeronycteris mexicana*), and lesser long-nosed bat (*Leptonycteris yerbabuenae*). These bats are migratory, spending summers in the American Southwest and winters in Mexico and points further south.

Little is known about where bats hibernate in the southwestern United States and even less is known about their habitat requirements. Our goal has been to establish population estimates, ascertain the health of the colonies and monitor them for the presence of WNS, identify the baseline microbial communities within cave sediment of hibernacula, and characterize bat hibernacula habitat. We have embarked on a multiyear study of two national monuments in northern Arizona: Grand Canyon–Parashant and Wupatki National Monuments. Initial cave inventories were conducted for 11 Parashant caves, while winter use of two Wupatki caves had been confirmed by work conducted in the 1980s. At all Parashant and Wupatki caves containing hibernating bats, we conducted annual population counts for three and two years, respectively. This was done to establish a baseline against which future comparisons can be made. During the course of our work, we counted all bats detected and have identified each bat to the lowest taxonomic level possible—bats were either *C. townsendii* or myotine species (it is impossible to identify most myotine bats to species without handling them and this was not an option given their sensitivity during the hibernation period). We also photographed several bats from each roost and visually inspected bats for any signs of WNS, measured the location of each bat or cluster of bats from the cave floor, and plotted each observation on a cave map.

During the summers, colleagues and I returned to these caves to collect sediments so that baseline microbial communities may be established. Samples were analyzed by Jeff Foster at the Center for Microbial Genetics and Genomics at Northern Arizona University.

To characterize and model hibernacula habitat, we collected low-resolution 3-D map data, obtained the aspect (or orientation) of each cave entrance, and determined total length of each cave, as well as collected temperature, humidity, and barometric pressure data. For each cave, we placed up to 40 HoboPro remote data loggers on walls, ceilings, and cave floors, collecting hourly data for two years.

We determined two Parashant caves to be bat hibernacula and confirmed the continued use of the two Wupatki caves as hibernacula. One of the Parashant caves, which contained at least 50 individuals, is the largest-known hibernaculum in northern Arizona. We examined hibernating bats and characterized the microbial communities residing within the cave sediment and, as expected, *P. destructans* was not detected in any of the sediment samples.

This large hibernaculum became the focus of intensive research. We collected three-dimensional bat roost locations for each bat observed during our second hibernacula count in 2012. The following summer, I returned to this cave with a team, which included Explorers Club member Pete Kelsey and his team from AutoDesk, Inc., to collect high-resolution (2 cm^2) 3-D data using a LiDAR laser scanner. In addition to capturing 3-D cave mapping data, each microclimate instrument location was plotted within the 3-D space. We are now in the process of plotting all bat and microclimate instrument locations within the 3-D model of this cave. We will be using these data to develop 3-D interpolative maps of cave climate.

Through this work, all hibernacula caves in Parashant and Wupatki have been closed to recreational use and all non-hibernacula related research must occur when the bats are not in residence. We collected important baseline information to characterize the microclimate requirements of these hibernacula roosts (which may be useful in extrapolating microclimatic conditions required for hibernating bats in northern Arizona in general), as well as baseline information on microbial communities of the hibernacula caves. The 3-D microclimatic models will enable us to better understand why bats select micro-sites for hibernation within caves and, more broadly, which variables characterize bat hibernacula habitat in the American Southwest.

While there is much uncertainty concerning exactly how bats in the region will respond to WNS and to what extent North American bats will recover, strong collaboration between land managers and conservation biologists will improve our knowledge concerning the locations of bat roosts (including hibernacula, maternity and bachelor roosts) and cave-roosting bat habitat requirements, and may enable us to find a way to manage for WNS. Researchers and land managers have developed a national response plan to help guide collaboration (see www.whitenose syndrome.org).

While there is no mighty Excalibur sword that conservation biologists can wield to stop WNS, there are a few mitigation strategies available to researchers and the general public. First, anyone entering a cave or mine should follow the WNS measures provided by the U.S. Fish and Wildlife Service (www.whitenosesyndrome.org/topics/decontamination). Also, many caves and mines have been closed because of WNS; so, it is always advisable to check with landowners or managers before entering any cave or mine. Second, we need to continue to educate the public regarding the importance of bats and the threats bat populations currently face. Finally, we need to improve our knowledge, especially in areas unaffected by WNS, concerning cave-roosting bat roost locations, population estimates, and habitat information (as described above) so that science-based decisions may be made to help protect and conserve many of North America's dwindling bat populations.

FLAG #139 EXPEDITION MEMBERS FROM LEFT: CHRIS HOLCOMB, JUT WYNNE, GREG FLORES, PETE KELSEY, MIKE KOTANIAN, AND TODD HECKMAN.