Bats and white-nose syndrome

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Since March 2006, white-nose syndrome (WNS) has killed hundreds of thousands of bats in the American northeast and adjacent Canada (1). Most of the mortality has been documented in species that use underground hibernation sites (i.e., caves and mines). Little brown bats (*Myotis lucifugus*; Fig. 1) have been the most frequent victims. The first evidence of the lethal impact of WNS emerged during annual counts of hibernating bats conducted under the auspices of the New York State Department of Environmental Conservation. The ascomycete *Geomyces destructans*, a cold-loving (i.e., psychrophilic) fungus, causes the symptoms associated with WNS. In PNAS, Warnecke et al. (2) report that *G. destructans* isolates from Europe and North America caused WNS in little brown bats. This raises the specter that people (bat workers or cave explorers) are responsible for the introduction of WNS into caves in the United States.

This seminal work (2) demonstrates that *G. destructans* affects bats by increasing the frequencies of arousal from the torpor of hibernation. The results support the hypothesis that *G. destructans* kills bats by altering their ability to hibernate. The only energy source available to hibernating bats is stored body fat. Each arousal from hibernation costs energy that could fuel 60 d of torpor (3). Quite simply, infection with *G. destructans* means that bats exhaust their supply of stored energy long before the end of winter. For temperate animals that eat arthropods, mainly insects, there are few prey available in mid-winter, which means virtually no prospect of replenishing fat reserves.

The negative impact of human disturbance of bats during hibernation was a fundamental reason for installing gates on caves and mines they used for hibernating bats. Population decreases associated with disturbance in these crucial sites was the principal reason that two species, *Myotis sodalis* and *Myotis grisescens*, were listed first as vulnerable (1982) and then as endangered (1996) in the United States (4). Hibernation also can make bats vulnerable to climate change (5).

Bats are small. The 1,259 living species of bats range in size from adult masses of 2 to 1,500 g. Most species weigh less than 50 g as adults. In addition to their sensitivity during hibernation, bats are vulnerable for at least three other reasons.

Fig. 1. A little brown bat (*M. lucifugus*) flies through an abandoned mine during swarming. After the arrival of WNS, the numbers of hibernating bats in this mine decreased from more than 14,000 in October 2009 to just more than 2,600 in November 2011.

First, unlike other small mammals, bats have low reproductive output, with most species in temperate regions bearing a single young each year. Second, bats differ from other small mammals because they can live long lives, the current record being more than 40 y in the wild (6). Third, failure to survive their first winter means that many temperate bats do not reproduce (7). The massive die-offs caused by WNS pose a serious threat to the survival of some species of bats.

In the American northeast, some bat biologists predict that little brown bats will be extirpated by WNS before 2020. WNS has spread rapidly (8), and in its wake, summer and winter roost sites that used to harbor hundreds or thousands of bats are now empty or scarcely populated. In my opinion, WNS has shown us, in a macabre way, just how mobile bats can be. Surely the spread of WNS reflects the extensive late summer dispersal of bats that takes place during "swarming" (9). This prenuptial, prehibernation behavior involves movements between caves and mines that will serve as hibernation sites. Band recoveries from earlier studies revealed that a few banded bats (compared with the number tagged) had moved hundreds of kilometers (9). The spread of WNS suggests that the magnitude and frequencies of movements indicated by banded bats during swarming were conservative.

Biologists concerned about the conservation of bats are quick to identify them as providers of important ecosystem services (e.g., refs. 10, 11). Bats have high metabolic rates, which generate voracious appetites (11). Active insectivorous bats regularly consume at least 50% of their body mass in food every summer night, and, for lactating females, the number exceeds 100% (11). It follows that many people living in the United States and Canada believe that local bats eat mainly mosquitoes and are responsible for holding their populations in check. However, DNA barcoding allows identification of the species of insects eaten by bats and reveals that little brown bats, for example, rarely eat mosquitoes (12). Furthermore, those concerned about the control of malaria do not even mention the possible role of bats as a means of controlling mosquitoes (13). However, when data on food consumption by bats are applied to species of bats that form huge colonies (millions of individuals—e.g., Brazilian free-tailed bats, *Tadarida brasiliensis*), the impact on populations can be astonishing (14). For most species of bats, however, the presumption of biocontrol of insect pests remains more a wish than a reality supported by data.

By 52.5 Mya (the Middle Eocene), bats were well established and diverse, with at least 10 families represented (15). The majority of living species occur in the tropics and subtropics and will not be affected by *G. destructans* if it is limited to cold situations.

The association of bats with diseases such as rabies, and the presence of three species of blood-feeding vampires, combine to tarnish the reputation of bats. Yet, at least in the United States and Canada, there is considerable public support for bats and concern about the impact of WNS on their populations. The life histories of temperate bats suggests that they have little capacity for quick reestablishment of their populations. This same feature makes them vulnerable to other threats, notably the impact of mortality at "wind farms" (16, 17).

Even with the work of Warenke et al. (2), we are left with more questions than answers. Will little brown bats and other species survive the impact of WNS? Can infected bats recover from WNS? Will isolated populations of little brown bats, perhaps in the Queen Charlotte Islands or Newfoundland, survive WNS? What happens when some sympatric species are removed from a community of bats? What happens to populations of

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See companion article on page 6999.

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COMMENTARY

insects after removal of some of their major predators? Will listing little brown bats and other affected species as "at risk" (e.g., endangered) make any difference to the trajectories shown by populations of affected species of bats?

Whatever the answers to these questions, we would miss bats because they are a mainstay of mammal diversity. Furthermore, their small size, mobility, long life spans, and the variety of trophic roles they fill in ecosystems makes them excellent candidates as bioindicators (18).

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