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Letters to the Editor

Editor's Note: Unlike technical articles, letters are not peer-reviewed, but they are edited for grammar, style, and clarity. Letters provide an outlet for opinions, speculations, anecdotes, and other interesting observations that, by themselves, may not be sufficient or appropriate for a technical article. Letters should be no longer than two manuscript pages and sent to the Feature Editor.

Is White-nose Syndrome Causing Insectivory Release and Altering Ecosystem Function in Eastern North America?

David S. Jachowski[1], Catherine M.B. Jachowski[1], and W. Mark Ford[2]

[1]*Department of Fisheries and Wildlife Conservation, 106 Cheatham Hall, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061, and* [2]*U.S. Geological Survey, Virginia Cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife Conservation, 106 Cheatham Hall, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061*
E-mail: djachowski@gmail.com

White-nose syndrome, caused by the fungal pathogen *Pseudogymnoascus destructans*, has resulted in catastrophic collapse in populations of cave-hibernating bats in eastern North America (U.S. Fish and Wildlife Service, 2012). First documented in New York in 2006, the fungus has spread to almost all states and provinces east of the Great Plains (U.S. Fish and Wildlife Service, 2014). The epizootic has resulted in a greater than 90% reduction in the formerly predominant species of bat in the Northeast, the little brown bat (*Myotis lucifugus*), and dramatic declines in several other cave-roosting species (Reeder and Moore, 2013).

Biologists have focused most attention on direct effects of the disease on bats, with little consideration to the broader, indirect ecological effects of such rapid and precipitous declines in a formerly abundant mammalian insectivore. Preliminary evidence suggests that remnant populations (i.e., individuals or species less affected) in the Northeast are taking advantage of newly available niche space resulting from the precipitous declines (Jachowski et al., 2014). However, abundance and foraging activity of remnant bats are much lower than before white-nose syndrome (Ford et al., 2011). Thus, it is unlikely that remnant populations are replicating former levels of insectivory in these systems.

In this letter, we estimate the total biomass of insects that is no longer removed as a result of the catastrophic declines in populations of bats in eastern North America. Although the loss of bats was estimated to be at least 5.7 million individuals by 2012 (U.S. Fish and Wildlife Service, 2012), detailed monitoring data from before and after white-nose syndrome is limited to 42 hibernacula in five states—New York, Pennsylvania, Vermont, Virginia, and West Virginia (Reeder and Moore, 2013). We used the proportional rates of declines at these sites to extrapolate the estimated number of total bats lost by species as a result of white-nose syndrome that total to 5.7 million individuals (Table 1).

We created a simple, species-specific, energetics-based model to estimate the annual biomass of insects no longer consumed by bats following white-nose syndrome. Although the biomass of insects that a bat eats

Table 1. Six species of bat impacted by white-nose syndrome in eastern North America and the per-individual, estimated, annual biomass of insects consumed. To calculate an estimate of the total number of bats lost by species, we applied reported species-specific loss percentages that were based on pre- and post-white-nose syndrome surveys at 42 hibernacula in New York, Pennsylvania, Vermont, Virginia, and West Virginia (Reeder and Moore, 2013) to the broader estimate of 5.7 million total bats killed by white-nose syndrome (U.S. Fish and Wildlife Service, 2012). Average body masses were taken from Best and Jennings (1997), Caceres and Barclay (2000), Kunz et al. (1998), Kurta and Baker (1990), Perry and Thill (2007), and Thomson (1982). The per-capita estimated annual biomass of insects consumed (g) was calculated by multiplying average body mass for each species by the average biomass of insects consumed per night as a proportion of the bat's body mass (0.25) and the average number of nights active each year (180 nights).

Species of bat	Estimated contribution (%) to the 5.7 million bats lost	Average body mass (g)	Per-capita estimated annual biomass of insects consumed (g)
Big brown bat, *Eptesicus fuscus*	0.3	17.0	765
Eastern small-footed bat, *Myotis leibii*	0.04	4.4	198
Little brown bat, *Myotis lucifugus*	87.7	8.2	369
Northern long-eared bat, *Myotis septentrionalis*	0.5	6.5	293
Indiana bat, *Myotis sodalis*	10.9	7.3	329
Tricolored bat, *Perimyotis subflavus*	0.6	5.5	248

varies seasonally and with a suite of factors such as individual condition and reproductive state, studies of captive individuals conservatively suggest that bats consume 25% of their body mass in insects each night (Kunz et al., 1998; Kunz et al., 2011). Therefore, we estimated per-capita nightly consumption of insects by multiplying the average weight of a species by 0.25. We then estimated the rate of annual insectivory for an individual by multiplying this nightly value by 180, which is the approximate number of nights that bats are actively foraging between April and October (Davis and Hitchcock, 1965; Table 1). This per-capita estimate of annual insect consumption was then multiplied by our estimate of total individuals lost to produce a species-specific estimate of lost insectivory each year (Table 1).

Our analysis suggests that the yearly consumption of insects has declined by over 2,079 metric tons (Fig. 1). To put this into context, Whitaker (1995) used fecal analysis to estimate that a single big brown bat (*Eptesicus fuscus*), on average, consumes 10.63 stinkbugs (Pentatomidae) per night; therefore, white-nose syndrome has potentially resulted in about 2.3 million fewer stinkbugs being consumed annually by big brown bats alone. In addition, stinkbugs only make up a small (2–16%) proportion of the diet of big brown bats, and declines in the other five species of bats are expected to result in billions of coleopterans, dipterans, hemiopterans, homopterans, hymenopterans, lepidopterans, trichopterans, and arachnids no longer being consumed (Whitaker, 2004), which will have unknown ecosystem-level consequences. Further, as white-nose syndrome spreads across North America, insectivory release is likely to occur across a wider range of taxa, raising the potential for

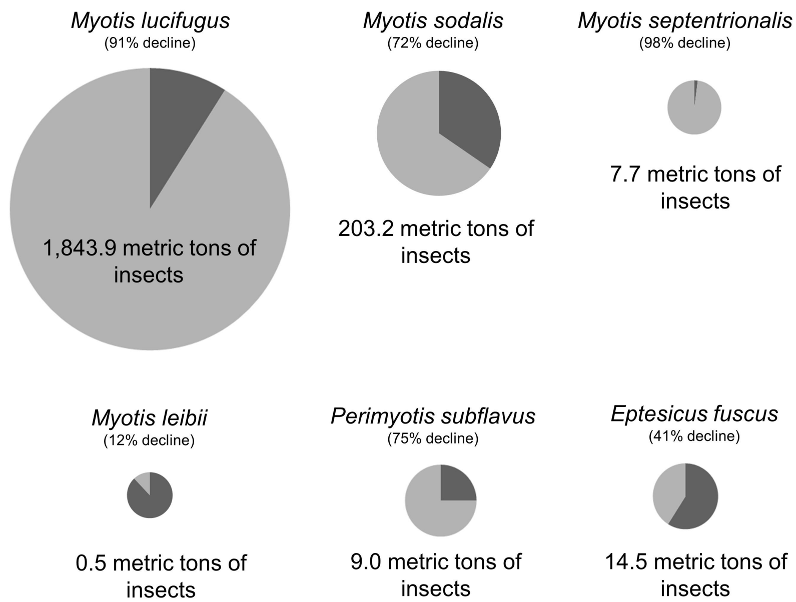

Figure 1. Estimated biomass of insects no longer being consumed because of white-nose syndrome, based on declines in six species of bat in the eastern United States that total to 5.7 million individuals lost. Size of circles represents historical abundance and the fractional percentages in light grey represent the percent population reduction for each species following arrival of the disease, based on data collected from 42 hibernacula in five eastern states where white-nose syndrome has been present for at least 2 years (Reeder and Moore, 2013).

losing important ecosystem-service benefits that bats provide by consuming agricultural and forest pests (Boyles et al., 2011).

In addition to direct predation, communities of insects are also likely being indirectly altered by the relaxation of predation risk. The predation risk posed by bats has led to the evolution of defense mechanisms by insects, ranging from altered activity periods to acoustical jamming (Kunz et al., 2011), and even ultrasonic broadcasts that resemble the calls of bats can reduce mate-seeking behavior and reproductive output of insects (Huang and Subramanyam, 2004). Therefore, in addition to investigations into how white-nose syndrome is causing some level of insectivory release by bats no longer directly consuming insects, research is urgently needed to determine the extent to which the indirect effects of declines in insectivory could be impacting communities of insects and the broader functioning of ecosystems.

Our preliminary analysis highlights the importance of not only directing research toward declining populations of species of conservation concern, but also to considering the potential cascading, indirect, ecological effects of emerging infectious diseases, such as white-nose syndrome. Increasing evidence suggests that emerging infectious diseases have transformative power over ecosystems, shifting the structure and function of biological communities (Cobb et al., 2012; Hartley et al., 2009). To evaluate more effectively the potential role of white-nose syndrome and other emerging infectious diseases as transformative ecological agents, we encourage research into their broader, long-term, direct and indirect ecological effects.

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