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- POLICY FORUM

CONSERVATION

Economic Importance of Bats in Agriculture

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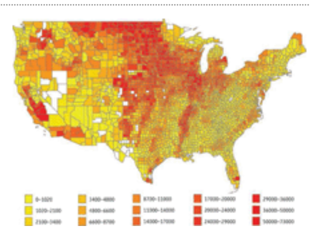
White-nose syndrome (WNS) and the increased development of wind-power facilities are threatening populations of insectivorous bats in North America. Bats are voracious predators of nocturnal insects, including many crop and forest pests. We present here analyses suggesting that loss of bats in North America could lead to agricultural losses estimated at more than $3.7 billion/year. Urgent efforts are needed to educate the public and policy-makers about the ecological and economic importance of insectivorous bats and to provide practical conservation solutions.

Infectious Disease and Wind Turbines

Insectivorous bats suppress populations of nocturnal insects (1, 2), but bats in North America are under severe pressure from two major new threats. WNS is an emerging infectious disease affecting populations of hibernating cave-dwelling bats throughout eastern North America (3). WNS is likely caused by a newly discovered fungus (*Geomyces destructans*). This fungus infects the skin of bats while they hibernate and is thought to trigger fatal alterations in behavior and/or physiology (e.g., premature depletion of energy reserves) (3, 4). Since February 2006, when WNS was first observed on bats in upstate New York, *G. destructans* has spread west of the Appalachian Mountains and into Canada. To date, over one million bats have probably died, and winter colony declines in the most affected region exceed 70% (5). Populations of at least one species (little brown bat, *Myotis lucifugus*) have declined so precipitously that regional extirpation and extinction are expected (5).

At the same time, bats of several migratory tree-dwelling species are being killed in unprecedented numbers at wind turbines across the continent (6, 7). Why these species are particularly susceptible to wind turbines remains a mystery, and several types of attraction have been hypothesized (6). There are no continental-scale monitoring programs for assessing wildlife fatalities at wind turbines, so the number of bats killed across the entire United States is difficult to assess. However, by 2020 an estimated 33,000 to 111,000 bats will be killed annually by wind turbines in the Mid-Atlantic Highlands alone (7). Obviously, mortality from these two factors is substantial and will likely have long-term cumulative impacts on both aquatic and terrestrial ecosystems (5, 7). Because of these combined threats, sudden and simultaneous population declines are being witnessed in assemblages of temperate-zone insectivorous bats on a scale rivaled by few recorded events affecting mammals.



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The worth of insectivorous bats.

Estimated annual value of insectivorous bats in the agricultural industry at the county level. Values (×$1000 per county) assume bats have an avoided-cost value of ~ $74/acre of cropland (12). (See SOM for details.)

Economic Impact

Although much of the public and some policy-makers may view the precipitous decline of bats in North America as only of academic interest, the economic consequences of losing so many bats could be substantial. For example, a single colony of 150 big brown bats (*Eptesicus fuscus*) in Indiana has been estimated to eat nearly 1.3 million pest insects each year, possibly contributing to the disruption of population cycles of agricultural pests (8). Other estimates suggest that a single little brown bat can consume 4 to 8 g of insects each night during the active season (9, 10), and when extrapolated to the one million bats estimated to have died from WNS, between 660 and 1320 metric tons of insects are no longer being consumed each year in WNS-affected areas (11).

Estimating the economic importance of bats in agricultural systems is challenging, but published estimates of the value of pest suppression services provided by bats ranges from about $12 to $173/acre (with a most likely scenario of $74/acre) in a cotton-dominated agricultural landscape in south-central Texas (12). Here, we extrapolate these estimates to the entire United States as a first assessment of how much the disappearance of bats could cost the agricultural industry [see supporting online material (SOM)].

Assuming values obtained from the cotton-dominated agroecosystem in Texas, and the number of acres of harvested cropland across the continental United States in 2007 (13), we estimate the value of bats to the agricultural industry is roughly $22.9 billion/year. If we assume values at the extremes of the probable range (12), the value of bats may be as low as $3.7 billion/year and as high as $53 billion/year. These estimates include the reduced costs of pesticide applications that are not needed to suppress the insects consumed by bats (12). However, they do not include the "downstream" impacts of pesticides on ecosystems, which can be substantial (14), or other secondary effects of predation, such as reducing the potential for evolved resistance of insects to pesticides and genetically modified crops (15). Moreover, bats can exert top-down suppression of forest insects (1, 2), but our estimated values do not include the benefit of bats that suppress insects in forest ecosystems because economic data on pest-control services provided by bats in forests are lacking. Even if our estimates are halved or quartered, they clearly show how bats have enormous potential to influence the economics of agriculture and forestry.

Although adverse impacts of WNS on bat populations have occurred relatively rapidly, impacts of wind energy development appear to pose a more chronic, long-term concern. WNS has caused rapid and massive declines of hibernating bats in the northeastern United States, where this disease has persisted for at least 4 years (5). Thus, the coming growing season may be the first in which the adverse effects of this disease will become noticeable. Because of regional differences in crop production, the agricultural value of bats in the U.S. Northeast may be comparatively small relative to much of the United States (see the figure) (SOM). However, evidence of the fungus associated with WNS was recently detected in the Midwest and Great Plains, where the estimates of the value of bats to agriculture are substantial (see the figure). Additionally, because this region has the highest onshore wind capacity in North America, increased development of wind energy facilities and associated bat fatalities in this region can be expected (16). Thus, if mortality of bats associated with WNS and wind turbines continues unabated, we can expect noticeable economic losses to North American agriculture in the next 4 to 5 years.

Policy

A recently stated goal of the United Nations Environment Programme is to demonstrate the value of biodiversity to policy-makers and the public (17). In keeping with this goal, we hope that the scale of our estimates and the importance of addressing this issue will resonate both with the general public and policy-makers. Bats provide substantial ecosystem services worldwide, and their benefits to human economies are not limited to North America. For example, pioneering research in tropical ecosystems shows the importance of plant-visiting bats in the pollination of valuable fruit crops (18, 19). Although the economic impacts of mass mortality of bats associated with WNS appear to be confined, at present, to North America, wind turbines are also causing bat fatalities in Europe (20), and the potential for WNS to spread to other parts of the world is unknown.

We suggest that a wait-and-see approach to the issue of widespread declines of bat populations is not an option because the life histories of these flying, nocturnal mammals—characterized by long generation times and low reproductive rates—mean that population recovery is unlikely for decades or even centuries, if at all. Currently, there are no adequately validated or generally applicable methods for substantially reducing the impacts of WNS or wind turbines on bat populations. To date, management actions to restrict the spread of WNS have been directed primarily toward limiting anthropogenic spread (e.g., cave and mine closures and fungal decontamination protocols) (21). Other proactive solutions for understanding and ameliorating the effects of WNS include developing improved diagnostics to detect early-stage infections and fungal distribution in the environment; defining disease mechanisms; investigating the potential for biological or chemical control of the fungus; and increasing disease resistance through habitat modification, such as creation of artificial or modified hibernacula that are less conducive to disease development and transmission (11, 22). Other approaches, such as culling of infected bats have been widely discussed and dismissed as viable options for control (23). New research also shows that altering wind turbine operations during highrisk periods for bats significantly reduces fatalities (*24*, *25*). Specific action on these issues will benefit from scientific research carefully aimed at providing practical conservation solutions for bats in the face of new threats and at assessing their economic and ecological importance. We as scientists should also make concerted efforts to develop and use more effective methods for educating the public and policy-makers about the ecosystem services provided by bats.

Bats are among the most overlooked, yet economically important, nondomesticated animals in North America, and their conservation is important for the integrity of ecosystems and in the best interest of both national and international economies. In our opinion, solutions that will reduce the population impacts of WNS and reduce the mortality from wind-energy facilities are possible in the next few years, but identifying, substantiating, and applying solutions will only be fueled in a substantive manner by increased and widespread awareness of the benefits of insectivorous bats among the public, policy-makers, and scientists.

Supporting Online Material

www.sciencemag.org/cgi/content/full/332/6025/41/DC1

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