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Our Neighbors, Bats!

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ABSTRACT
Bats have existed on earth for at least 50 million years and during that time, different species have evolved to fit in diverse environments and ecological niches. Bats are the only group of mammals with "true powered flight," meaning they can flap their wings and propel themselves through the air (versus glide). Scientists believe that it is this unique ability that's facilitated their speciation and wide distribution around the globe. Yet while bats are seemingly everywhere, their numbers are also declining, often due to human actions. This synthesis covers the basic biology and ecology of bats, the ecosystem services they provide, the threats they face globally, and how conservation actions can mitigate these threats.

BATS! THE BASICS

Of the 6,500 or so different mammal species on the earth, approximately 1,406 are from one group—bats! (Burgin et al. 2018; Simmons and Cirranello 2019). That means over 20% of known mammal diversity are bats.

Bats are like other mammals in that they are endotherms (or regulate their body temperature internally through metabolic processes) and they have hair (though some baby bats are notably hairless). Also, like other mammals, bats have mammary glands and feed their young with milk (fun fact—their nipples are in their armpits!) (Wilson 1997). What makes bats truly unique from other mammals though, is their ability to fly. Bats are collectively known as the order Chiropetra, which means "hand wings" because their forelimb digits (like our fingers) have a membrane between them that creates wings (Taylor and Tuttle 2019). Other mammals, such as flying squirrels and sugar gliders, have mastered the ability to glide through the air after jumping from high places thanks to membranes connecting their forelimbs and hindlimbs, but bats are the only group of mammals that have "true powered flight," meaning they can flap their wings and propel themselves through the air (Taylor and Tuttle 2019).

Although bats do have good eyesight (about the same as human eyesight[i]), some bats also have the ability to echolocate—they emit high-pitched sounds and sense the echoes of the sound off of the objects in the environment—which greatly improves their ability to fly during the night. This "bio sonar" allows bats to hunt prey in low (or no) light, detect obstacles, and navigate home to their roosts (where they sleep, take care of young, and where they might hibernate). Because they fly at night, bats are less likely to compete with or be hunted by most birds, which fly more frequently during the day. (Interestingly, there are four known bat species that hunt during the day, but they are only found on islands where predators are most likely absent; Rehm 2018). This reduction in competition and predation pressure has provided an opportunity for bats to thrive. Scientists believe that it is bats' unique ability to fly that's facilitated their speciation (the formation of new species through evolution) and their wide distribution around the globe (Taylor and Tuttle 2019).

But where are all these bat species? Have you seen a bat in the wild before? Even if you haven't, that doesn't mean they aren't nearby; bats are basically everywhere, with the exception of some remote islands and the polar regions. However, even though bats as a group are found on six of the seven continents, their diversity is not evenly spread out and some distribution patterns are evident—for example, the greatest number of species of bats (known as "species richness") are found in the tropics (Figure 1; BCI 2019a).

[i]Some might argue that bats see "better" than humans because, unlike humans, many bats can see into the UV range of light (see Gorresen, P.M., P.M. Cryan, D.C. Dalton, S. Wolf, and F.J. Bonaccorso 2015. Ultraviolet vision may be widespread in bats. Acta Chiropterologica 17(1):193–198).

Chiroptera (Bats)

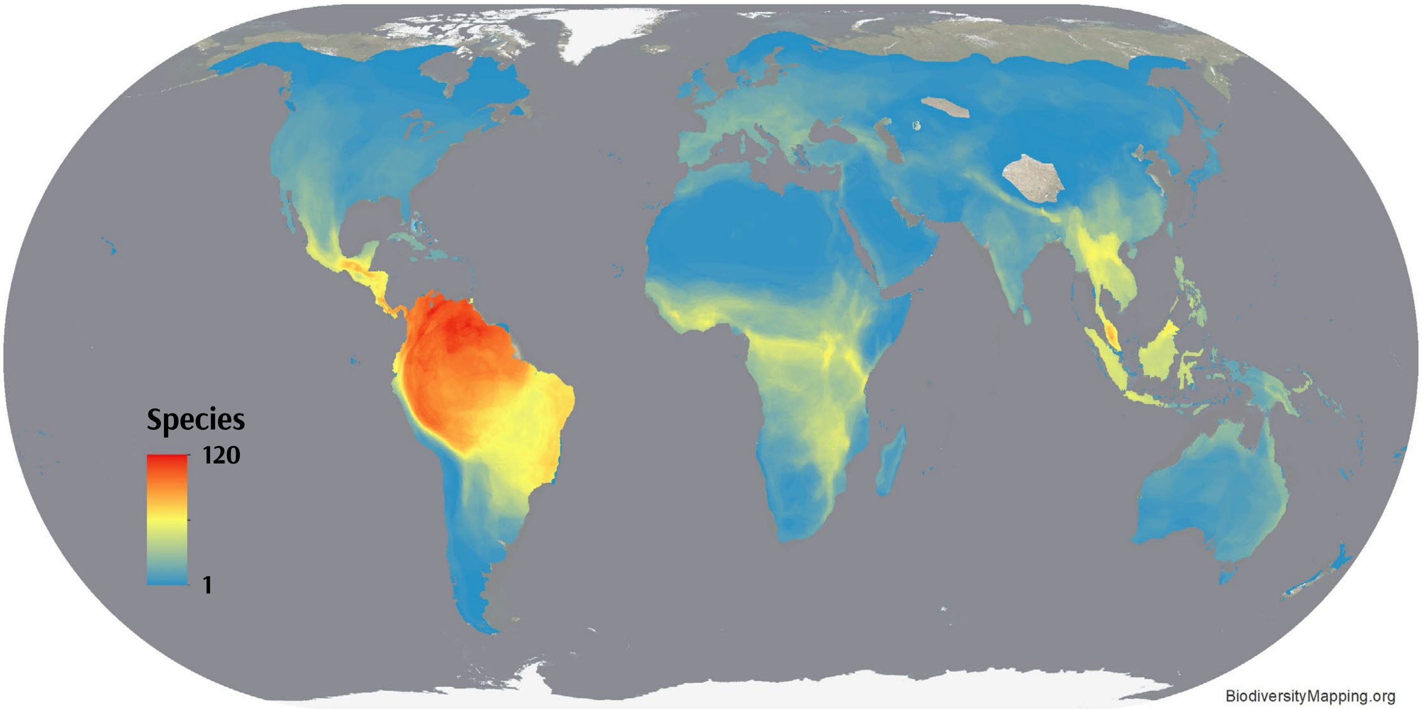

Figure 1. Map of bat species richness. Bats are not found in Antarctica, the Arctic, and gaps in distributions elsewhere are often are associated with high mountain ranges and desert regions. Image credit: C.N. Jenkins/Instituto de Pesquisas Ecológicas (map based on IUCN March 2018 data) biodiversitymapping.org/wordpress/index.php/mammals/.

Despite this pattern of more bat species found in tropical regions, bats can be found in diverse habitats such as arid deserts, temperate forests, and even cities! Nor are they restricted to caves, as you might think. Bats can roost in other natural structures such as rock and cliff crevices and trees, but also in human-constructed mines, roofs and attics, stadiums, bridges and more (BCI 2019a).

Bats have existed on earth for at least 50 million years and during that time, different species have evolved to fit in differing environments and ecological niches. The difference between species includes not only their appearance, but also their diets and behaviors. For example, the bumblebee bat (scientific name, *Craseonycteris thonglongyai*, and also called the Hog-nosed Bat and Kitti's Hog-nosed Bat) is considered the smallest bat in the world; it is smaller than your thumb and weighs less than a US penny (2.5 g) (Figure 2A; Taylor and Tuttle 2019; BCI 2019b). It is only known to roost within 43 different caves in Southeast Asia (Myanmar and Thailand), and feeds exclusively on insects (an insectivore) within a 1 km radius of its roosting cave (Taylor and Tuttle 2019). In comparison, another bat found in Southeast Asia, the large flying fox (scientific name, *Pteropus vampyrus*, and also called the Malayan flying fox, kalang, or kalong) is one of the largest bats in the world with a wingspan of up to five feet (~1.5 m), and it roosts in trees and eats fruits (a frugivore) (Figure 2B; Taylor and Tuttle 2019).

Bats can vary in color and color patterns, and have a wide variety of shapes (morphologies) of their face and ears (Figure 3). All of these differences are the result of evolution over large time scales (i.e., hundreds of thousands of years), leading to adaptations to different types of landscapes and communities of species (like the types of food and predators in an area). To get an inside look on how scientists study bat evolution, check out this video: www.amnh.org/explore/videos/shelf-life/shelf-life-14-into-the-island-of-bats.

According to Taylor and Tuttle (2019), until relatively recently, bats have traditionally been placed into two groups based on differences in their appearance and biology: the microbats (like the Bumblebee Bat) and the megabats

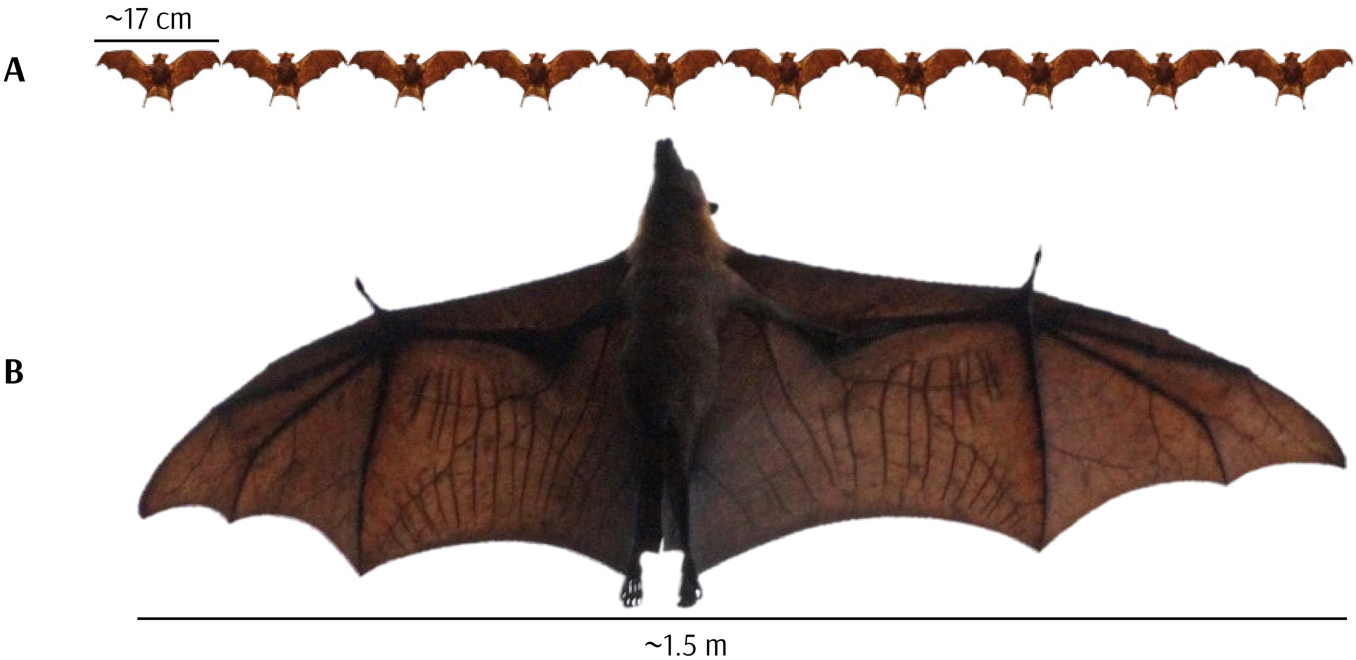

Figure 2. Compare the wingspans! A large flying fox's (B) wingspan is almost as long as 10 bumblebee bats (A)! Photo credit: (A) Jerry Oldenettel/Flickr (CC BY-NY-SA 2.0), (B) Momotarou2012/Wikimedia Commons (CC BY-SA 3.0).

*Figure 3. Bats don't all look or act the same. (A) Honduran White Bats (*Ectophylla alba*) are all white with yellow snouts and ears and they roost in "tents" they make from large leaves. (B) Spotted Bats (*Euderma maculatum*) have pink wings, ears nearly as long as their bodies, and are known to roost on cliffs along the Grand Canyon among other places. (C) Pale Spear-nosed Bats (*Phyllostomus discolor*) have a fleshy appendage on their noses called a "nose-leaf" which may help with echolocation and they roost in hollow trees or in caves. Photo credit: (A) Leyo/Wikimedia Commons (CC BY-SA 2.5 ch), (B) Bureau of Land Management/Fickr (CC BY 2.0), (C) Karin Schneeberger alias Felineora/Wikimedia Commons (CC BY 3.0).*

(like the Large Flying Fox). The microbats are smaller (hence "micro"), are often predators that hunt mainly insects (but can also hunt other prey such as rats, birds, frogs, other bats, or might also be omnivorous or herbivorous), have smaller eyes with short snouts, and sometimes have large ears and fleshy appendages on their noses to help with echolocation. The megabats are bigger ("mega"), more likely to feed on fruit or nectar, and have larger eyes and elongated snouts. Megabats normally have better eyesight and sense of smell than microbats, to help them locate their fruit or nectar food source, and are less reliant on echolocation. Instead of making echolocation noises with their larynx as most microbats do, most megabats don't echolocate at all, or they use tongue-clicking or even click their wings to help with navigation (Taylor and Tuttle 2019).

However, researchers that use genetics to study bats have found that the story is a bit more complicated. In fact, some microbats are actually more closely related to megabats than to other microbats! These researchers have suggested two new categories for bats, Yinpterochiroptera and Yangochiroptera, though the common grouping of "micro" and "mega" is often still used in non-scientific literature. The relationship between, and evolution of, these groups is still being studied, but one thing is for sure—even though some microbats look remarkably like flying rodents and some megabats look like primates (e.g., lemurs), bats are not closely related to these groups. Bats are actually more closely related to carnivores, hoofed mammals, whales, and pangolins—quite a wide range of different evolutionary relatives (Taylor and Tuttle 2019)!

Regardless of category, all bats require habitat that provides adequate food, water, and places to roost. Depending on where a species lives and what they eat, some bats might need to change locations or behaviors throughout the year to find and manage the resources they need. For example, some insect-eating bats breed in temperate climates but lose their food source during the winter (flying insects that aren't present in the winter); therefore, these bats might either migrate to warmer climates where insects are available year round or might find roosting locations that can protect them while they hibernate (i.e., when they reduce their metabolism and living off fat stores in their body during winter). In these temperate regions, roosts are also important in the summer for rearing young and resting during the daytime. Some roosts can house several species of bats and be used year after year, while others might be temporary and only used seasonally. As mentioned earlier, not all roosts are large communal caves (like Bracken Cave, see Box 1). In addition to roosting inside or on natural (tree/cliff) crevices and human-constructed structures, some bats have been found roosting inside termite nests, colonial spider webs, pitcher plants, and even crocodile burrows! A few species even make their own roosts—for example, the Honduran White Bats (*Ectophylla alba*) create shelters by biting and manipulating large leaves to make tents (see Figure 3A above; Taylor and Tuttle 2019).

BATS ARE PART OF THE ECOSYSTEM AND SO ARE WE!

Bats' relationships with each other, other species, other groups, and their surrounding environment all contribute to their role in their ecosystems. Bats are part of the food web: for example, insectivore bats act as the primary predators of night-flying insects, but they themselves also are important prey for animals such as hawks, snakes, and other mammals like racoons (Taylor and Tuttle 2019; BCI 2019c). Some bats that live in the tropics contribute to the ecosystem in other ways, like pollinating plants and dispersing seeds, which helps plants reproduce and helps establish food sources and shelter for other species (BCI 2019c). For example, bats are the main pollinator of the great baobab tree, found in the savannahs of East Africa. This species of tree is often called the "African Tree of Life" because so many other species depend on it—and in turn, all of those species rely on bats to maintain great baobab tree populations (BCI 2019c). More food for thought—have you ever eaten a mango, guava, or banana? All of these fruits come from plants that are pollinated by bats (US Forest Service 2019)!

There are other ways that bats help form or shape an ecosystem. For example, the floors of communal roost caves are coated in excrement known as guano. Guano provides nutrients for other species—nutrients that the cave normally wouldn't have available. In caves where bats and, consequently, guano are present, complex communities form, including species such as beetles, cockroaches, centipedes, and other invertebrates (Deharveng and Bedos 2019). If bats were to leave these caves, these ecosystems might not be able to sustain themselves.

Humans also benefit from having bats in their ecosystems. "Ecosystem services" are the benefits that humans obtain from their ecosystems (IPBES 2019), such as the air we breathe, water we drink, and food we eat. So, what are the ecosystem services that bats provide?

Pest Control

The majority of bat species are insectivores and they eat insects such as moths, beetles, flies, and mosquitoes, in both land and aquatic ecosystems (Taylor and Tuttle 2019). Some of the insects they eat are considered

Box 1: Bat Facts! Did You Know...?

Bracken Cave in Texas has the largest colony of bats in the world, housing approximately 10 million Brazilian Free-tailed Bats (*Tadarida brasiliensis*). Recently scientists clocked the Brazilian Free-tailed Bats reaching top speeds of 100 miles per hour (161 km per hour)! These bats also reach altitudes of 10,000 ft (3048 m) on migratory flights that can be up to 310 miles (498 km) a night. If you are interested, check out a short news clip to see what it looks like to be in or near Bracken Cave when bats emerge: https://www.sciencefriday.com/segments/catching-a-texas-batnado/.

A. Brazilian Free-tailed Bat

Most female bats only have one baby (called a pup) a year but invest a lot of time and energy into rearing their pup (sometimes with the help of other females in the communal roost).

Some bats, like the "mouse-eared bats" from the genus *Myotis*, have been recorded to live to more than 40 years old.

B. Greater Mouse-eared Bat

Wing shape can affect a bat's flight and hunting abilities: short and wide wings result in agility and allow for greater maneuverability at slower speeds. This is good for hunting insects, especially in dense areas of trees. Longer and narrower wings lead to faster and more efficient flight, which helps with catching fast-flying insects in open areas.

Like amphibians, bats can exchange gas through their skin (i.e., expel carbon dioxide and take in oxygen)—up to 10% of total exchange has been observed in the Wahlberg's Epauletted Fruit Bat (*Epomophorus wahlbergi*).

C. Wahlberg's Epauletted Fruit Bat

Fringe-lipped Bats (*Trachops cirrhosus*) catch frogs on the ground and can identify and avoid toxic-bodied species by listening and identifying frogs' mating calls. Other species of bats are fish hunters and grab prey from the under the water's surface with their large feet.

Most bats don't drink blood. Only three species of "vampire" bats exist, and they don't attack prey and suck blood. Instead, these bats make a painless incision on the skin of a sleeping animal and then lap up the blood that drips out with their tongue.

D. Fringe-lipped Bat

Vampire bats are also famous for possibly exhibiting a behavior called altruism (meaning an individual helps another at its own expense). The Common Vampire Bat (*Desmodus rotundus*) has been seen returning to roosts and regurgitating blood to other bats, most often to a bat it's related to but also unrelated individuals. Turns out that those who receive meals are more likely to pay back the favor and donate meals in the future! To learn more about vampire bats and their evolution, check out this video: www.amnh.org/explore/videos/research-and-collections/molecular-adaptation-in-vampire-bats.

E. Common Vampire Bat

Facts derived from Taylor and Tuttle 2019; Photo credits: (A) National Park Service/public domain, (B) Manuel Werner/Wikimedia Commons (CC BY-SA 3.0), (C) Bernard Dupont/Wikimedia Commons (CC BY-SA 2.0), (D) Karin Schneeberger alias Felineora/Wikimedia Commons (CC BY 3.0), (E) Uwe Schmidt/Wikimedia Commons (CC BY-SA 4.0).

agricultural pests, meaning they damage crops and reduce farmers' ability to produce high quality food and plant products. How much does this matter? Well, for one example, there is an especially pesky moth, called the corn earworm moth, that loves to eat commercial plants such as corn, tomatoes, cotton, artichokes, watermelons, and more when it is a larva (caterpillar) (Figure 4; BCI 2019c). According to a study done by Josiah Maine and Justin Boyles in 2015, worldwide, the cost of crop damage caused by this moth is estimated to be more than one billion US dollars (USD) a year! Luckily for the farmers of south-central Texas, each evening millions of Brazilian Free-tailed Bats emerge from nearby caves like Bracken Cave (see Box 1) and from under bridges (like Congress Avenue

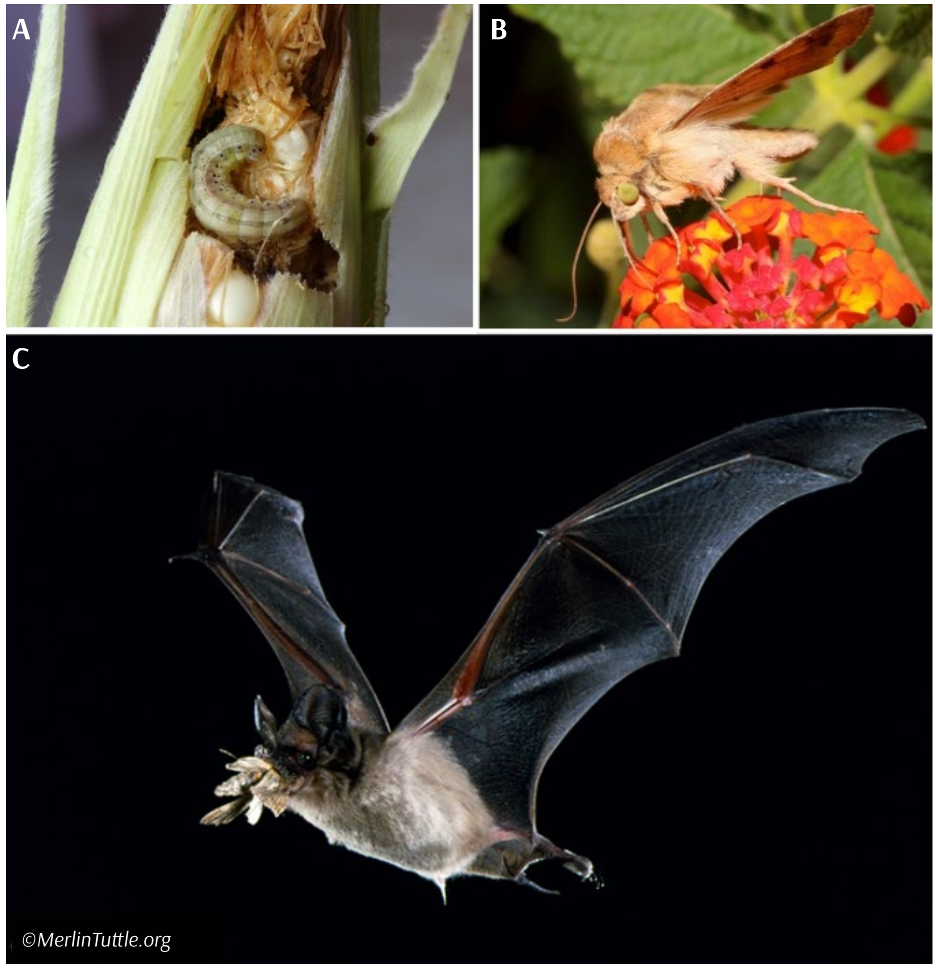

Figure 4. Control of the corn earworm moths! Adult moths are a favorite food of many insectivore bats and that's a good thing because if there are fewer moths, that means that there are fewer eggs laid and fewer larvae (caterpillars) that emerge and eat commercially important crops. Photo credits: (A) Corn earworm larva: Scot Nelson/Flickr (public domain), (B) Corn earworm moth: Lon&Queta/Flickr (CC BY-NC-SA 2.0), (C) Brazilian free-tailed bat eating moth: ©MerlinTuttle.org.

Bridge in Austin, Texas) to feast on insects, including the corn earworm moth (BCI 2019c; Medellin et al. 2017). In 2006, Cutler Cleveland, a researcher from Boston University, and his colleagues estimated that for cotton farmers in this region alone, this natural pest control was equivalent to USD $741,000 a year. Now consider all of farms across North America—scientists estimate that the agricultural benefits bats provide is worth over 3.7 billion US dollars each year (Boyles et al. 2011). Not only are bats reducing direct crop damage by eating the pests, their service also reduces farmers' need to apply harmful pesticides, lowering overall monetary and environmental costs (BCI 2019c).

Pest control from bats also benefits all of us with protection from pests like mosquitos. Mosquitos are annoying, to be sure, but they also can be determintal or even deadly if they carry and spread diseases like malaria, zika, and dengue fever, so the reduction in mosquitos that bats provide is also service to human health. While mosquitos are not a large part of insectivore bats' diets, a study determined that when bats predate on mosquitos, fewer mosquito eggs are laid—meaning that bats could still help to keep mosquito numbers down (Reiskind and Wund 2009).

Pollination and Seed Dispersal

When you think of pollinators, you probably think of bees. It's true that bees are exceptionally important pollinators, but nectar-feeding bats also serve this ecological role. Bats are attracted to flowers that have nectar and stay open at night. When they burrow their heads in the flower to lap up the sugary snack, their faces get covered in pollen from the male organs of the flowers (stamens); they end up transferring that pollen on the next flower they visit (on the female organ, the pistil). This process can lead to fertilization which can lead to seeds and fruits developing—seeds and fruits that support many other species and help the plants propagate. It is estimated that over 500 plant species are pollinated by bats (though not necessarily exclusively), and some of those species are commercially important crops and products such as agave (the source for tequila), balsa wood, bananas, cloves, guava, peaches, and durian (see Figure 5; Taylor and Tuttle 2019; BCI 2019c).

In the tropics, another group of bats (fruit-eating bats) might actually eat the fruits that are produced by plants pollinated by nectar-feeding bats! After digesting these fruits, bats will excrete the seeds that were inside the fruit in their guano. Moreover, because these bats can fly long distances and defecate while in flight, they often deposit seeds far away from the parent plant. This allows for seeding plants to grow away from the competition of their parent, and also for the spread of a plant species into new or open areas. Many of the seeds dispersed by bats are considered "pioneer" plants, meaning they are hardy and able to grow in areas that might be hotter or drier than other nearby areas (like clearings that have relatively few other plants). In some areas, the seeds dropped by bats can account for up to 95 percent of new plant growth in a cleared area (BCI 2019c). Once these pioneer plants start to grow, the surrounding conditions become less harsh (e.g., shading decreases heat and increases moisture), which allows for other less hardy plants to take root and grow, providing more complex habitat for other animals. This dispersal of seeds is a critical service for the ecosystem and for humans because it assists with the restoration of forests damaged or destroyed by deforestation. Regenerating healthy forest ecosystems is a complex process and it's difficult for humans to accomplish without the help of seeds being dispersed by bats and other groups of species like primates, birds, and rodents.

Note that not all humans are benefited by frugivore bats living nearby. Fruit farmers, for instance, may consider bats a pest species because they eat their crops. We'd call this an ecosystem disservice. Unfortunately, the loss of bats' natural habitats and food sources (through events such as forest clearing or droughts) intensifies damage to crops by fruit-eating bats. There are strategies to help prevent, reduce, or mitigate crop loss due to bats, including restricting the clearing of existing habitat for new agriculture and trying to prevent access to existing fruit crops, through covering fruits with netted bags, covering trees with netted tents, or covering entire orchards with nets supported by frames. These solutions require cooperation at many levels, including farmers, communities, governments, and corporations tackling large systemic issues such as climate change and deforestation.

*Figure 5. The Dawn Bat (*Eonycteris spelaea*) is the only effective pollinator of the flowers of the durian tree (A) and the pollination of the tree leads to the durian fruit (B)—often considered one of the smelliest fruits in the world. Although not a particularly popular fruit in the US, the sweet tasting fruit is very popular in Asia; Thailand alone produces almost 600 million US dollars worth of durian each year (Bumrungsri et al. 2009; Ghanem and Voigt 2012). Photo credits: (A) ©MerlinTuttle.org, (B) DXLINH/Wikimedia Commons (CC BY-SA 3.0).*

Bat Products and Ecotourism

Guano is nutrient rich and therefore considered a valuable natural fertilizer. It can be harvested and sold for agricultural purposes—the guano from one cave can yield up to USD $100,000 each year (Taylor and Tuttle 2019)! Guano is a renewable resource only if harvested sustainably. Harvesting practices that are insensitive to bat populations (such as modifying the cave) can be detrimental to bat colonies, leading to their decline or abandonment of the caves (Elliot 1994; Hutson et al. 2001). For example, in places like Cuba and Borneo, many bat species only roost in "hot caves" that have temperatures up to 40°C (104°F) and relative humidity near 100% (Wendel 2015; AMNH 2016). Part of what makes these caves so hot and humid is their shape and dimensions, but also the thousands of bats inside and the heat generated by decomposing guano. If the guano is harvested, the temperature of the caves could drop and make the cave too cold for the bats, which could lead to a colony collapsing. However, not all bats specialize to live in "hot caves" and guano harvesting can provide substantial economic benefits for local communities when done responsibly and in consideration of the needs of the particular bat species (Taylor and Tuttle 2019).

Bat products are also advancing medicine. Vampire bats (see Box 1) have anticoagulants in their saliva (named "draculin" after the popular character Dracula) that prevent the blood from clotting while they drink (Apitz-Castro et al. 1995). Researchers are studying draculin to see how it could be used in medicines to help reduce the risks of blood clots which cause strokes (Morgan 2011).

Finally, a not so well-known or widespread benefit of bats is ecotourism. In a 2013 study, Kenneth Bagstad and Ruscena Wiederholt found that over 242,000 annual visitors come to see bats such as the Brazilian Free-tailed Bat (see Box 1) at 25 major roosts across six states in the Southwestern US. The authors estimate that tourist visitation is worth over $6.5 million US dollars in economic value each year. One of the locations studied was Austin, Texas, where thousands of visitors come to view some of the largest-known urban bat colonies emerging during summer evenings from their roosts under bridges. Not able to travel to Austin to check it out? Watch this short video for an inside look: www.pbs.org/video/the-bat-bridges-of-austin-texas-eaxyxv/.

THREATS TO BATS AND HUMAN-BAT INTERACTIONS

Most bat species are declining in numbers everywhere they are found (BCI 2019d). In addition to loss of life from natural predators, bats are threatened by habitat loss, disturbance while hibernating, disease, wind turbines, climate change, and even intentional killing by humans.

Predators

Bats are part of the food web—they are predators of other species and they themselves are eaten by other species. Birds of prey, cats, and even snakes that hang from tree branches are known to wait outside of roosts and snatch the bats as they emerge in the evenings (Figure 6; Taylor and Tuttle 2019). Large swarms of bats leaving a cave all at once might seem like a feast to these predators, but this is also a good strategy for bats to ensure "safety in numbers"—the probability of any one bat being caught is reduced by the sheer number of other bats that are available for the predator.

Free-roaming cats (both pets and feral cats) are efficient predators and often considered an invasive species (because humans have assisted them to live in areas that they don't exist naturally, allowing cats to prey on species that did not naturally evolve to avoid or defend against them). Have a pet cat? To help wildlife in your area, consider neutering your cat to help reduce the number of feral cats and keeping your pet cat inside. Want a cat? Consider adopting a cat that might otherwise be free-roaming.

Hibernation is also a time when bats are prone to mortality events. Some predators have specialized in raiding bat roosts and eating the bats while they hibernate. For example, raccoons in North America prey on hibernating

Figure 6. (A) A black rat snake eating a brown bat. (B) A feral cat in New Zealand and some of the remains of 107 dead short-tailed bats. Photo credits: (A) Zack Bittner/Flickr (CC BY-NC-SA 2.0), (B) Department of Conservation (NZ) (CC BY 4.0).

bats and wood mice in the Netherlands have been observed cracking open the skulls of hibernating bats, like nut shells, and eating their brains (Moseley et al. 2013; Haarsma and Kaal 2016)! The bats—in a basically non-animated state of hibernation—are unable to fly away, defend themselves, or warn others of the threats.

Diseases

In North America, another threat that attacks hibernating bats is the cold-loving fungus, *Pseudogymnoascus destructans*, which causes the disease White-nose Syndrome (WNS) (BCI 2019d). This disease is called White-nose Syndrome because a tell-tale sign that a bat has contracted the disease is a white fuzzy growth, often on their noses (Figure 7). An infection can lead to bats waking up early from their hibernation state and subsequently starving because they don't have the enough reserves stored up in their body to sustain a calorie costly non-hibernation metabolism (Frick et al. 2016). While this fungus is commonly found in Europe and Asia, bats there seem to be resistant to its effects. This is most likely because those species evolved with the fungus present, allowing individuals who were resistant to survive and, generation after generation, pass on their successful and fungus-resistant genes. Meanwhile, in North America, bat species were not exposed to this fungus and did not acquire resistance over evolutionary time. The fungus was first recorded in North America in New York in 2006; as of 2019, WNS has been identified in 33 US states, and is estimated to have affected at least 15 different species, killing up to seven million bats (Taylor and Tuttle 2019). Given that more than half of US bats hibernate in caves and mines, and it is these species that are especially susceptible to this disease, WNS could be considered the largest threat to North American bats. In some populations in North America, fungus-resistant bats appear to be surviving and scientists hope that this natural resistance passes on to new generations, thereby preventing the total collapse of colonies and even the extinction of species bats (Langwig et al. 2017; Taylor and Tuttle 2019). Unfortunately, the fungus is still spreading to new colonies, and infected bats are being recorded each year in areas that the disease wasn't previously known to occur. If you'd like to learn more about WNS including the current extent of the disease, check out the White Nose Syndrome Response Team website www.whitenosesyndrome.org/ or you also could check out this video called "Battle For Bats: Surviving White Nose Syndrome" vimeo.com/76705033.

The WNS outbreak is considered an ecological disaster for North American bats and could have far-reaching effects on their ecosystems, but normally, bats are not especially susceptible to diseases. For example, fruit bats in Africa and Asia can act as natural reservoirs for certain viruses and diseases because they themselves are not affected or are only slightly affected by the infection (Schneeberger and Voigt 2016). Unfortunately, some of these pathogens are much more deadly when they pass into human hosts. Ebola, Marburg virus, Nipha virus, and other viruses have the potential of spreading from bat hosts to humans or other mammals. The transmission

Figure 7. Bats infected with WNS. Photo credit: Government of Alberta/Flickr (CC BY-ND 2.0).

of these viruses is still poorly understood, but there is evidence that diseases can be transmitted to humans through interaction with the body fluids of bats (blood, feces, and saliva) (Schneeberger and Voigt 2016). Rabies is another example and the only example of a viral disease associated with bats in North America and Europe (Schneeberger and Voigt 2016). Like other mammals, bats can contract rabies but it isn't considered a significant source of mortality, and it is rarely transmitted to humans (Taylor and Tuttle 2019). Even if a human is exposed to rabies, the probability of getting infected with rabies is virtually to zero if people are treated appropriately with a post-exposure vaccine after a bat scratch or bite (Schneeberger and Voigt 2016).

Although people do fear the rare possibility of disease transmission, there are ways to live safely with bats. First and foremost, experts say the best preventive measures include not handling bats (dead or alive) or their bodily fluids. If there was an instance where you did need to interact with a bat (for example, bats roosting inside your home), there are safe ways to deal with these situations that reduce both risks to you and the bats. If you'd like to learn more, check out the informative informational guide from PREDICT One Health Consortium: How to Live Safely with Bats downloadable at www.ecohealthalliance.org/living-safely-with-bats.

Loss of Habitat

As with most animals, the largest threat to bats is loss of habitat. Bats have very specific needs, especially in relation to roosting habitat, and human activities such as clearing land for agriculture, pastures, human developments like cities, and mining operations have all played a part in destroying or degrading areas where bats roost (BCI 2019d). Habitat loss can also lead to the reduction of food sources, especially for fruit-eating bats in the tropics. This can lead to human-wildlife conflict: if their natural habitat no longer supports them, these bats may depend more heavily on local farmers' fruit crops. Bats also need adequate water sources. Bats don't land to drink but instead swoop down over open water and scoop up a mouthful of liquid (Taylor and Tuttle 2019). These swooping motions require open space above the water, sometimes 13 to 100 feet (4 to 30 meters) in length, and landscape alterations that lead to the reduction of open waterways is another threat to bats and their habitat.

Fragmentation of habitat may also require bats to change the way they use their habitat. For example, some bats might avoid open areas that make them susceptible to predators and prefer to stay within densely wooded areas. Habitat fragmentation constrains these species to smaller areas, which might not provide all the resources they need. Roads are one way that habitats are fragmented and they also can introduce additional threats such as pollution (including noise and light pollution) as well as a source of mortality via vehicle collisions (Altringham and Kerth 2016). In some situations, roadkill might be high enough to lead directly to population decline (Altringham and Kerth 2016).

The loss of habitat for bats can also lead to health risks for humans. With deforestation and human expansion into bat habitats, especially in the tropics, people and bats are interacting in formerly remote areas; more interaction could lead to increased risk of disease transmission (EcoHealth Alliance 2019).

Climate Change

Habitat loss is also due to the degradation of the habitat. When habitat is degraded, for example due to climate change, bats may not have the resources they need for foraging, roosting, or successful reproduction. Remember Bracken Cave (Box 1)? Like other cave-roosting species, the Brazilian Free-tailed Bats are dependent on a cave with very specific temperature ranges. Higher temperatures appear to be affecting this cave and scientists have noticed some bats leaving (Taylor and Tuttle 2019). If warming trends continue, it's possible that caves like Bracken might not be able to sustain the numbers of bats that they currently do. Where will the bats go? How will that affect pest control and other ecosystem services bats provide in that area?

Climate change has also led to intensified weather events, such as droughts, that can reduce or otherwise impact food and water sources. As mentioned above, in the tropics, these stressful conditions can drive bats into agricultural areas, which in turn can lead to human-wildlife conflict as farmers attempt to protect their crops.

Climate change is a problem that affects the entire earth system (including ecological, economic, and human systems); it's a "systemic" problem that doesn't have just one solution. However, there are big questions we humans must address, including how we produce energy and reduce the amount of carbon that we put into the atmosphere, to help mitigate our changing of the earth's climate.

Wind Farms

Wind energy is considered a clean alternative to fossil fuels and can help with mitigating climate change—but its production is not environmentally neutral. For example, wind turbines (Figure 8) are a threat to bats (and some other flying species) (Arnett et al. 2016). In the US, scientists estimate that hundreds of thousands of bats are killed because of wind turbines (BCI 2019d). Mortality events are related to direct collisions with the blades, but bats also might suffer inner ear damage and other internal injuries such as ruptured blood vessels caused by the rapid pressure change (Arnett et al. 2016; BCI 2019d).

So, do bats just accidently run into wind turbines? Interestingly, it looks like collisions aren't by chance, and bats might actually be attracted to wind turbines, either as possible locations for roosts or because the turbines attract insects, which the bats feed on (Arnett et al. 2016). With the continued growth of the wind energy sector, scientists and companies are actively researching methods to monitor and mitigate bat deaths caused by turbines. For example, one study conducted in Pennsylvania found that turning wind turbines off when wind speed was low led to 44–93% fewer bats dying each night while only reducing power production by <1% of the total amount of power produced in a year (Arnett et al. 2011).

Hunting and Other Human-Bat Interactions

In parts of Africa, Southeast Asia, and some Pacific islands, bats are hunted for both local consumption and for commercial markets (e.g., restaurants) (Mildenstein et al. 2016). Bats are also hunted by people for a variety of reasons besides for food, including their perceived medicinal properties or human health threats, for decoration (e.g., teeth used for necklaces), and for sport (often urban residents and tourists seeking adventure) (Mildenstein

Figure 8. Wind farms can cover large expanses of land and lead to bat (and bird) mortality. Photo credit: USFWS/Joshua Winchell/Flickr (CC BY 2.0).

et al. 2016). Bats might also be hunted for retaliatory reasons. As previously mentioned, fruit farmers frustrated with the loss of crops may resort to shooting bats they see near their farm (Aziz et al. 2016).

Hunting pressure affects approximately 13 percent of bat species (at least 167 species) and is more common for large-bodied megabats (Mildenstein et al. 2016). Although pretty widespread, the effects of hunting on bat populations are poorly understood. Experts suggest more research is needed, in addition to education programs to reduce the negative impacts of hunting on bat populations and possible disease spread events (Mildenstein et al. 2016).

Humans also directly impact bat species by disturbing roost sites. Inappropriate guano mining or thoughtless tourism may disturb bats during hibernation, causing them to rouse (and subsequently lose too much of their stored up energy, weaken, and have a reduced likelihood of surviving the winter) (BCI 2019d). Human visits to roost sites could also have the indirect effect of introducing and spreading the WNS-causing fungus. Many tourist attractions are now requiring visitors to walk through boot cleaning stations prior to entering the caves, in an effort to prevent an accidental introduction of the harmful fungus (Frick et al. 2016).

ENDANGERED STATUS AND CONSERVATION

Although bats are seemingly everywhere, their numbers are also declining, often due to human actions. The International Union for the Conservation of Nature (IUCN) is an international environmental network of scientific experts that study the evidence available for each species to determine their level of threat and risk of extinction globally; this work is known as assessing a species. For each species assessed, the IUCN looks at criteria such as the population size and the rate population size decline, the size of the species geographic distribution (how widespread it is), and the degree of fragmentation of populations (whether they have been separated from each other) within that distribution. Based on these results, a species conservation status is determined. Of the approximately 1,300 bat species that have been assessed by the IUCN, almost a third are considered either threatened with extinction (i.e., given a conservation status of vulnerable, endangered, or critically endangered) or "data deficient" (meaning there is not enough data on the species to be able to accurately assess the level of threat to its existence) (BCI 2019d).

Some conservationists argue that all bats species should be protected and conserved regardless of their IUCN conservation status (Taylor and Tuttle 2019). A bat species' ecological value (or a species' roles and relationships in an ecosystem as well as the services they provide) may might be reduced even before their population numbers are critically low (Taylor and Tuttle 2019). In addition to the IUCN criteria, we should know how bats function within their ecosystems and conservation efforts need to try to maintain these functions. Luckily, there are dedicated people out there studying bats, monitoring their numbers and health, teaching others about the benefits of bats, and coming up with both small steps and grand plans to protect bats and their ecosystems. If you'd like to learn more about how you can help bat species in your neighborhood, consider installing a bat house (Box 2)!

Box 2. Bat Houses: Become a Bat Landlord!

Bat houses (also known as bat boxes) are constructed or purchased wooden boxes that are designed to provide habitat for bats. These houses may be mounted on the sides of buildings, walls, or even poles. Especially in areas where roosting locations may be sparse, bat houses can provide a valuable resource for bats to rest during the day, raise young, and even hibernate in the winter! By installing bat houses, you could be making your local area more bat-friendly.

Additionally, installing bat houses can also be a helpful way to get rid of unwanted bat roommates. Bats occasionally will roost inside human homes and are considered a nuisance. If you need to evict bats from your house, it's best to seal up any small holes they might use to gain re-entry, but also consider build them their own house—become a bat landlord and mount a bat house nearby!

There are great resources to get instructions on how to build or where to buy, how to install, and how to monitor these houses. Check out Bat Conservation International's website for a great place to start: www.batcon.org/resources/getting-involved/bat-houses.

Photo credit: US Air Force photo/Samuel King Jr.

COMPREHENSION QUESTIONS

1. What are three new things you learned about bats from this essay and why did they interest you?
2. What makes bats unique from other mammals? How are they similar to other mammals?
3. What are ecosystem services? Explain at least two ecosystem services that bats provide including why these services are important to humans.
4. Describe three threats to bats and what conservation actions people/organizations/governments do you think could help.

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