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How North America's Bats Survive the Winter
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by Merlin D. Tuttle

From late summer into fall, many North American bats prepare for the long winter ahead, storing the fat reserves they will need to last until spring. In most places, winter means a shortage of food for insectivorous animals. Facing a choice of migrating to a warmer climate and remaining active, or going into hibernation, most bats in the northernmost and mid‑latitudes choose hibernation. Some begin to travel to hibernation sites as early as September, while others migrate south to warmer climates.

Where bats go in winter was one of my earliest scientific curiosities. When I was in high school in eastern Tennessee, my friends and I often explored local caves, one of which contained thousands of bats that appeared only briefly in spring and fall. I identified them as gray bats *(Myotis grisescens*), learning from books that they were nonmigratory, supposedly living in the same caves year-round. After observing the annual pattern of their arrival and disappearance for several years, I became convinced that this was not the case and that gray bats indeed migrated. Excited about the potential significance of my observations, I arranged to meet with biologists at the Smithsonian. They encouraged me to band some of the bats to see if I could learn where they were going.

When the bats returned in early October, I banded 300, hoping someone farther south would find them in winter. By a stroke of luck, my father and I found them ourselves only a month later. They were hibernating in a cave with more than 100,000 others, over 100 miles *north* of where we had banded them. Not only was this one of the first discoveries of a major gray bat hibernating site, but it was also the first real evidence that they migrated, all the more exciting since they had unexpectedly traveled north instead of south. The cave where I had first observed their brief appearances each spring and fall was a regular stopover on their way to a hibernation cave.

That discovery ultimately led to my banding thousands more gray bats over the entire southeastern U.S. Over some 20 years I followed their movements among hundreds of caves, learning that nearly all gray bats from Alabama, Florida, Georgia, Kentucky, Tennessee, and Virginia hibernate each winter in only four caves. My findings raised many questions about why they used less than 0.1% of the area's available caves in winter.

I learned that, along with a few other species adapted to mid-latitudes, gray bats migrate seasonally between exceptional caves whose configurations trap either warm or cold air. Those used by hibernating gray bats in northern Alabama and Tennessee, for example, are such efficient cold-air traps that cave temperatures never rise above 49 F at any time of year. These caves have large rooms or passages located below the lowest entrances, with at least one additional entrance above the main area of the cave. This creates a chimney effect, expelling warm air and trapping cold air. Large volumes of trapped air ensure relative temperature stability and protection from freezing. Very few caves have these special configurations that make them ideal hibernation sites.

Hibernating bats typically require relatively stable temperatures between 32 F and 49 F. In contrast, summer nursery colonies need temperatures of close to 60 F or more, preferably 70 F or above to successfully rear young. Cave temperatures generally approximate mean annual surface temperatures, which in mid-latitudes of North America range between 50 F and 60 F. Except in the northern United States and Canada, most North American

caves are too warm to permit bats to hibernate in them. And except in the South, most caves are too cold for rearing young, explaining why cave-dwelling bats used less than 5% of caves in my study area at any time of year.

Bats are among the few true hibernators. The winter sleep of animals such as bears is often mistaken for hibernation, but it lacks the marked metabolic and physiological shutdown of a true hibernator. The breathing of a hibernating bat is imperceptible, and its body cold to touch. Its heartbeat drops from roughly 400 beats per minute, when awake, to about 25 in hibernation, and its body temperature drops to within a few tenths of one degree of the surrounding cave.

Even in hibernation, a bat must periodically arouse to drink or urinate, or sometimes to find a cooler or warmer spot within the cave as temperatures fluctuate. Moisture from the cave walls, or the condensation on their fur, provides drinking water. A little brown bat (*Myotis lucifugus*), for example, may arouse at intervals of only 12 to 19 days, but also may hibernate uninterrupted for as long as 83 days, depending on temperature and other conditions. As the winter wears on, the fat a bat has stored during fall is slowly metabolized. These limited reserves must last it anywhere from five to eight months.

The amount of fat stored often depends on how far a bat must migrate--the longer the journey, the more energy required. Gray bats, with lean body weights of only about 8 grams, gain up to 8.6 grams of fat before their fall migration from Florida to northern Alabama and Tennessee. In contrast, gray bats that migrate less than 50 miles to reach the same hibernation caves store only 5.4 grams or less.

Most bats simply cannot afford to expend the energy needed for long distance travel. Furthermore, the wing design of most species is more adapted for aerial maneuverability than for speed or distance. These factors often mean that the summer distribution of bats is limited by the availability of nearby caves suitable for hibernation. Gray bats hold the record among cave-dwelling species, routinely covering up to 325 miles to reach a hibernation cave. But most bats, including the majority of gray bats, do not travel more than 200 miles one way, and typical distances are less than 100 miles. Many young do not survive their first trip or arrive with too little fat left to tide them over until spring.

Although young apparently learn routes of travel from adults, exactly how migrating bats locate hibernation caves is still unknown. During their first fall migration, young gray bats are always in the company of adults, often with only males. Arriving at their wintering caves from all directions, they do not just instinctively travel north or south. Cave entrances can be as small as three feet in diameter and invisible from more than a few feet away, demanding very precise navigation to find them. Since bat echolocation signals reach just a few yards ahead at best, one can only wonder how bats learn the way with the precision required to find obscure entrances hundreds of miles from the summer home where they were born. Gray bats tend to follow rivers, their preferred feeding habitat. Other species orient visually to mountain ranges. Field research revealed that even when migrating Indiana bats (*Myotis sodalis*) were blinded, they simply arrived a few days later than bats with vision. Such bats must have help from others or have impressive memories of topographic detail.

Not all bats travel great distances to find a place to spend the winter. The seasonal movements of many bats of western North America are only in elevation, some cave dwellers finding cool-enough winter roosts by moving higher, and some tree dwellers finding suitably mild climates by moving lower. A wide variety of western bats, from pallid bats (*Antrozous pallidus*) to western pipistrelles (*Pipistrellus hesperus*) and various myotis bats, move into deep rock crevices at elevations where average temperatures meet their hibernation needs. Tight contact with rock surfaces protects them from climatic fluctuations.

The tiny eastern pipistrelle (*Pipistrellus subflavus*) is apparently incapable of lengthy migration and has its own unique strategies for surviving winter. Unlike most bats, pipistrelles typically hibernate at about 50 F, sometimes up to 54 F, enabling them to use a much wider variety of caves. They roost alone, often occupying the exact spot on a cave wall from winter to winter. Pipistrelles choose hibernation sites where there are few temperature changes and where moisture readily condenses on their fur, preventing dehydration, and providing moisture to drink. During

hibernation, they arouse and move less frequently than other bats. Although they metabolize fat reserves more rapidly at higher hibernating temperatures, they apparently compensate for the loss by reducing the frequency of arousal.

Bats that live in trees instead of caves have different strategies for surviving the winter. Several of North America's most widespread bats live year-round in tree foliage or hollows. With the advantage of being able to live nearly anywhere trees are found, the distance to the nearest cave becomes unimportant. Red (*Lasiurus borealis*), hoary (*L. cinereus*), and silver-haired bats *(Lasionycteris noctivagans*) spend summers in the northern United States and Canada, heading south in August or September, often traveling in migratory waves along with small birds.

Some are known to overwinter in hollow tree cavities as far north as the Ohio River Valley. Red and hoary bats use their large, furry tail membranes just like a blanket. During the coldest weather, red bats have the ability to raise their metabolic rates enough to ensure a body temperature above their critical lower survival limit of 23 F. When winter temperatures rise above 55 F they arouse and feed, often in the brief warmth of mid-afternoon, in order to capture the few available insects.

Although some hoary bats spend the winter in a similar manner as red bats, most apparently migrate south into subtropical or tropical areas, many into Mexico where presumably they remain active. Silver-haired bats commonly overwinter in Illinois, Indiana, West Virginia, and Tennessee, and a few winter as far south as Arizona and Texas. They typically are found hibernating deep in cliff-face crevices, tree hollows, or even in woodpiles. Many tree-dwellers also overwinter in coastal areas as far north as Oregon and New York where winters are relatively mild.

Only one North American bat has adapted to living year-round in buildings in the northern half of the United States and Canada. If you live in this region and find a bat in your home or yard during winter, it is almost certainly a big brown bat (*Eptesicus fuscus*). Unlike most North American cave-dwellers, big brown bats can survive body temperatures well below freezing and are therefore able to hibernate in attics and wall spaces. I once captured several flying through a November blizzard with strong winds and an 18 F temperature. On another occasion, I found one on a cave wall trapped completely in ice except for its nose. When I carefully freed the bat, it awoke and flew deeper into the cave.

The most endangered bat species typically are those with the most narrow requirements for hibernation. Since very few caves meet the needs of endangered gray and Indiana bats, these bats can overwinter in only a few sites where they are extremely vulnerable. Northern Alabama's only hibernation cave houses more than a million gray and thousands of Indiana bats each winter, including more than half of the entire gray bat species population.

Sometimes, protection of a single site is crucial to the survival of one or more bat species over a several-state region. Several years ago, the owner of an old mine along the Mississippi River in Wisconsin wanted to fumigate the mine's roughly quarter million little brown bats so he could use the site for cheese storage. The bats had gradually moved in as humans increasingly disturbed their cave roosts. That single act would have eliminated numerous summer bat colonies throughout the region. Fortunately, intervention by BCI and other conservation groups prevented it.

Many bat hibernation sites already have been lost, making those that remain even more important. The most frequent problem is human disturbance. Species such as gray and Indiana bats, who form single dense clusters of tens of thousands of hibernating individuals, are especially vulnerable. Requiring up to an hour or more to arouse from hibernation, they cannot quickly fly away from danger, and in any event cannot leave their roost in winter. Helpless, thousands at a time have been intentionally killed by vandals. Many more die as a result of inadvertent disturbance by amateur cave explorers who do not realize the dire consequences of their actions.

Each human disturbance of a hibernation site causes many bats to arouse, often at great energetic cost. Even eastern pipistrelles, among the most tolerant of disturbance, waste 10 to 30 days of stored fat per arousal. Recent laboratory

studies conducted by Donald Thomas of the University of Sherbrooke in Canada, indicate that each time a little brown bat is disturbed during hibernation, it expends fat sufficient to have lasted for 67 days.

What Thomas found is that when the bat arouses from hibernation, it uses up 107.9 mg of fat, more if it must fly. During the course of a normal winter in northern latitudes, a typical little brown bat will arouse naturally about 15 times. For the mere 56 hours it spends awake during an average 193 day hibernation period, it expends an enormous 1,618.5 mg of fat, accounting for 84% of the fat it needs to get through the winter. In sharp contrast, while deep in hibernation the bat will use only a total of 308 mg of fat for an entire winter. This means that if a little brown bat stored the same amount of fat, but only had to awaken once in the spring to come out of hibernation, it would have had enough reserves to last about four and a half years.

But with the high cost of arousing, even this is sometimes not enough. During especially cold winters, they may need their extra reserves to seek out warmer parts of the cave. A severe winter compounded by human disturbance could spell disaster for a hibernating bat. Only three extra arousals beyond the normal number could cost the bat its life.

An incident in Virginia illustrates how vulnerable hibernating bats really are. In 1969, cave explorers invited me to see an enormous population of hibernating Indiana bats they had discovered a year earlier when they were repeatedly visiting the cave. From their observations of cluster sizes, I estimated that a minimum of several hundred thousand bats had used the cave. I discovered abundant evidence to support their reports and found conditions ideal for Indiana bats. But despite a thorough search of the cave, we found only about 1,200 remaining. Years later, searches revealed approximately the same number. What might have been one of the world's largest hibernating bat populations apparently was lost in a single winter due to human disturbance. With the bats' behavioral programming, and the rarity of such sites, it is very unlikely that they simply found another suitable cave.

Despite minimal disturbance in ensuing years, this Virginia cave has never recovered its former population, and despite federal protection, Indiana bat populations continue to decline. The cave's surviving bats likely are those that spent their summers nearby and thus required fewer fat reserves. Perhaps the bats that traveled from more distant summer habitat were those that died, leaving none behind that knew the migratory routes, a loss that could take hundreds of years to rebuild.

Loss of migratory stopover caves, such as the one where my gray bat studies began, also can have serious consequences. These roosts are often thought to be unimportant because bats use them only briefly in spring and fall. But suppose such a site provides the only suitable shelter midway between the bats' summer and winter roosts. Lack of a protected resting place could dramatically increase migratory mortality.

Conservation measures for all migratory cave-dwelling bats are urgently needed. Even the Mexican free-tailed bat (*Tadarida brasiliensis*), still one of our most abundant species, is in serious trouble in many places. Unlike most other North American cave-dwellers, huge populations from the southwestern United States travel south into the warmer subtropical and tropical climates of Mexico where they remain active through the winter.

With their long, narrow wings, designed for rapid flight, free-tails are masters of long-distance travel. Huge departing flocks in Central Texas may climb to as much as 11,000 feet, traveling on the strong tail winds that accompany the first major cold front in late October or early November. Although no one has followed the migrating bats or clocked their speed, it is conceivable that they may attain speeds of 80 miles per hour or more.

Free-tailed bats face serious threats in Mexico where people burn their overwintering caves, mistaking them for vampire bats (*Desmodus rotundus*). Millions of free-tails at a time can be killed with little, if any, impact on controlling vampires. Already, key free-tailed populations have declined dramatically in the United States. Eagle Creek Cave (formerly home to the world's largest bat colony) in Arizona dropped from between 25 and 50 million in 1960 to 30,000 less than 10 years later. New Mexico's Carlsbad Caverns declined from 8.7 million at the turn of the century to roughly a quarter of a million today.

Although many North American bats are hardy and adaptable, they are extremely vulnerable during migration and hibernation and cannot live without their chosen overwintering sites. Bats that have gradually abandoned caves for mines because of human disturbance are now in serious jeopardy. Mines are being closed for safety reasons, but without knowledge of the consequences to bats [see "Bats and Mines: Abandoned Does Not Always Mean Empty," page 13]. Migrating bats also face other hazards: even a remote cyanide-leaching pond, used to extract gold from ore, potentially can cause enormous mortality to migrating species [see "Bats, Cyanide, and Gold Mining, page 17].

Bat Conservation International already has been instrumental in gaining protection for several of the United States' largest remaining bat hibernation sites and is now launching efforts to protect overwintering habitat in Mexico [*BATS*, Summer 1991]. Biologists and professional cave explorers must work together to reduce disturbance to *all* bats that hibernate in caves--not just protecting those already listed as endangered.

One or more bat species may no longer live in your area for a number of reasons, but certainly human disturbance of overwintering caves has played an important role in their disappearance. Gray bats were once one of the most abundant mammals of the southeastern United States. Today they are endangered. Although only a fraction of their former numbers, gray bat populations are recovering in protected sites through conservation efforts. With greater understanding of bat needs, and continuing efforts to educate people about bats, we can help more bat species to recover and prevent others from becoming endangered.

Merlin D. Tuttle is Founder and Executive Director of Bat Conservation International.

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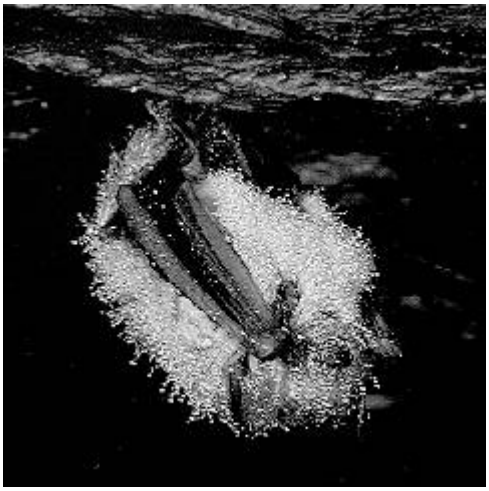
The most endangered bats are those with the most narrow requirements for hibernation. Only a few caves provide the necessary temperature and humidity conditions for endangered species such as these gray bats.

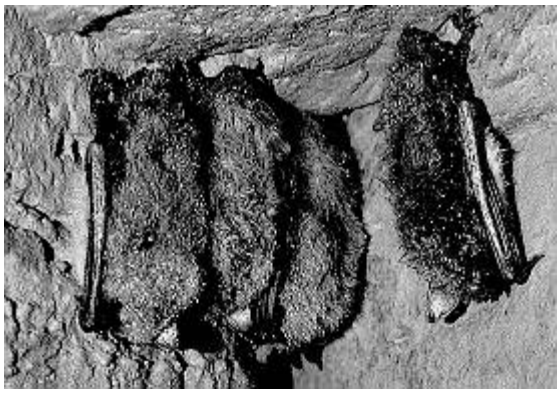
Bats are among the few true hibernators. Before entering hibernation, they store fat reserves which are slowly metabolized during the winter. Gray bats (left) sometimes more than double their body weight in fat.

Many North American bat species begin migrating to their chosen hibernation sites as early as September, some, such as this gray bat (above), traveling as far as 325 miles.

"Tree bats" do not require caves for hibernation, instead retreating to places such as tree cavities, cliff faces, and even woodpiles. Among the hardiest of bats, a red bat wraps itself in its large, furry tail membrane to retain body heat.



Eastern pipistrelles hibernate alone, often at the same spot on a cave wall year after year. Moisture condensation forms on their fur, preventing dehydration.



Disturbance during hibernation can cost bats their lives. Recent research shows that when hibernating little brown bats arouse, they use up stored fat sufficient to last 67 days.

Some bat species hibernate in dense clusters while others roost alone. Clustering may help reduce dehydration and temperature fluctuation, but it also makes bats extremely vulnerable to human disturbance and vandalism. These Indiana bats are among the United States' most endangered bats.

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