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Bats Aloft: A Study of High-Altitude Feeding
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By Gary F. McCracken

Millions of bats emerge from the cave, climb higher than the eye can see, and disappear in the evening sky. Returning in the murky light of early morning, the bats appear to swoop straight down from the stratosphere, opening their wings to brake with a "phssst" at the cave's entrance. While not actually the stratosphere, the altitudes to which Mexican free-tailed bats (*Tadarida brasiliensis*) fly is impressive. Radar studies of the bats from Bracken Cave in Texas show that they fly as high as 10,000 feet (3,000 m), with the densest aggregations at altitudes of 600 to 3,200 feet (200 to 1,000 m) above the ground. Why do these bats fly so high?

We know that the bats' nightly mission is to find food. Mexican free-tailed bats eat incredible numbers of insects. Extrapolating from the energy requirements of a mother and her growing pup, we estimate that a million nursing free-tailed bats eat about 10 tons of insects every night. At least 100 million migratory free-tails occupied the major maternity caves of Central Texas every summer back in the 1960s. That would total up to 1,000 tons (2 million pounds) of insects eaten each night--and this only by bats in the largest caves of Texas.

Could free-tailed bats be eating thousands of tons of insects at thousands of feet above the ground? If so, which insects? I've conducted research on these bats since 1981, and have pondered where they find their food ever since I saw my first bat exodus.

Until recently, most biologists assumed that bats do not harvest large numbers of insects at high altitudes. There was no evidence that sufficient numbers of insects existed at those altitudes. Also, foraging by bats has been observed and studied almost exclusively at heights near the ground, giving us, perhaps, a low-altitude bias. Free-tailed bats go to high altitudes, it was assumed, primarily to take advantage of prevailing winds that help them travel long distances to profitable foraging locations.

Dr. Don Griffin, who has studied bat foraging behavior since the 1930s (a most inadequate description of his accomplishments), took exception to this common assumption. In 1985, Griffin took Dr. Sid Gauthreaux and me aside at a scientific meeting and suggested that we collaborate on "bats aloft," his name for a study on high-altitude foraging by Mexican free-tailed bats. Griffin was aware of mounting evidence that large numbers of insects migrate at high altitudes, and he had already recorded bat echolocation calls at altitudes of up to 1,600 feet (500 m). While using radar to study nighttime migrations by birds, Gauthreaux had observed objects showing bat like foraging flight at altitudes of up to 2,600 feet (800 m). Griffin, Gauthreaux, and I spent a week in Texas in 1986, and we recorded free-tailed bat echolocation calls, including their feeding buzzes, at altitudes of about 600 feet (200 m). Afterwards, Griffin gave me several boxes of equipment and bequeathed the "bats aloft" project to me. I put it on the back burner, but never quite turned off the stove.

Because of the large numbers of insects they eat, it has long been assumed that Mexican free-tailed bats have substantial ecological and economic importance. When we started the PCMM initiative in 1994 (see "What is the PCMM?"), Dr. Merlin Tuttle and I argued this importance before the U.S. State Department as a major reason for

concern about the plight of migratory free-tails. The heat on "bats aloft" was turned up a bit.

In the spring of 1995, "bats aloft" came to full boil when the U.S. Weather Service's new Doppler radar was turned on at New Braunfels, Texas, only a few miles from Bracken Cave. Every night the Doppler radar detects the huge numbers of free-tailed bats that come out of Bracken Cave and other major roosts. It documents their dispersal over the Texas landscape, and it plots the altitudes and directions from which they return every morning. When I contacted Jim Ward at the Doppler radar facility, he was enthusiastic about using the radar to study high-altitude flight patterns of bats. After hearing the migratory insect hypothesis, Ward suggested that I contact Drs. Wayne Wolf and John Westbrook at the U.S. Department of Agriculture (USDA) Research Station at College Station, Texas. I won't soon forget the phone conversation with Wayne Wolf.

Wolf told me that in the first weeks of June, billions of corn earworm moths emerge from an agricultural region in the Lower Rio Grande Valley of Mexico. Emerging just after dusk, the moths ascend to hundreds of feet above the ground and catch prevailing winds that help them travel north--often more than 250 miles in a single night. Three days after the peak moth emergence in Mexico, the peak egg-laying period of corn earworms (also known as cotton bollworms) occurs in the agricultural region around Uvalde, Texas, west of San Antonio, where the moths lay eggs on corn, cotton, and other crops. About three weeks later, after their larvae have fattened on the crops, the next generation emerges from the Uvalde region and continues a northward "hopscotch," infesting agriculture through much of central North America. Throughout much of this region, corn earworms cannot survive winters, and their populations depend on migration. In terms of damage caused, corn earworms are the number-one agricultural pest in America. In terms of the pounds of pesticides used to control them, they rank behind only boll weevils.

The moths fly at the same altitudes as the bats, in the season when the bats have their greatest energy needs. Might free-tailed bats be eating large numbers of the number-one agricultural pest in America as it migrates from Mexico and invades much of the U.S. and Canada? "Perhaps, but," cautioned Wolf, "the moths leave Mexico at dusk and haven't yet reached Central Texas when the bats leave their caves in the evening. The migrating moths don't arrive in Central Texas until early morning."

I had just reviewed a manuscript by Drs. John Whitaker and Tom Kunz on free-tailed bat diets. Typically, the bats forage twice each night, leaving the cave in the evening and again in the early morning, returning to the cave to nurse their pups during the interim. Whitaker and Kunz's study, as well as earlier dietary work on these bats, showed that moths typically comprised about 30 percent of the diet of the bats that return to the cave around midnight. But Whitaker and Kunz also sampled bats as they returned at dawn. In mid-June, the diets of these bats showed a dramatic shift between the two feeding periods, from 37 percent moths at midnight to 96 percent moths at dawn. Here was striking evidence that the bats exploit the moths as the moths enter the region and become available.

Diverse lines of evidence all converge on the conclusion that free-tailed bats are taking advantage of the high-altitude migrations of major agricultural pests. Doppler radar information on bat flight patterns, the temporal shift in their diets, nitrogen and carbon isotopic ratios of guano from Carlsbad and Eagle Creek Caves, and the high fat content of their diets are all consistent with this conclusion.

Much research still must be done to assess the agricultural and economic importance of our free-tailed bat populations. Ya-Fu Lee, a student of mine, has made significant progress already, in conjunction with the PCMM and with scholarship support from BCI. Throughout the summers of 1995 and 1996, Lee worked in Texas to obtain comprehensive data on free-tailed bats' diet throughout the growing season, and to link their diets to what we now know regarding the timing of major insect emergences and migrations. In the last year, we have developed a DNA marker that allows us to identify gene fragments from corn earworms in the feces of bats that have eaten these pests. Using this marker, we can tell from analyzing a fecal pellet not only that a bat has eaten moths, but that it has eaten corn earworm moths. This summer, working with John Westbrook and his colleagues from the USDA, we placed radio microphones on weather balloons that floated freely with the moths. The radio microphones recorded bat orientation calls as high as 3,900 feet (1,200 m) and feeding buzzes at 2,400 feet (750 m), proving that

free-tailed bats are indeed flying and feeding at the same altitudes and locations as the moth migrations.

It has long been maintained that bats' insect consumption is valuable to agriculture, and particularly to local farmers (*BATS*, Spring 1993). Our linking of high-altitude foraging by free-tailed bats with the migrations of major insect pest populations provides the first demonstration of these bats' value on a much larger regional scale. This discovery greatly strengthens the persuasive power of the PCMM initiative and goes hand-in-hand with its educational program. People take care of the things they value, and we are quickly establishing a clear value for Mexican free-tailed bats. At the same time, we are sharing that knowledge with the people who can do the most to protect these amazing high-flyers.

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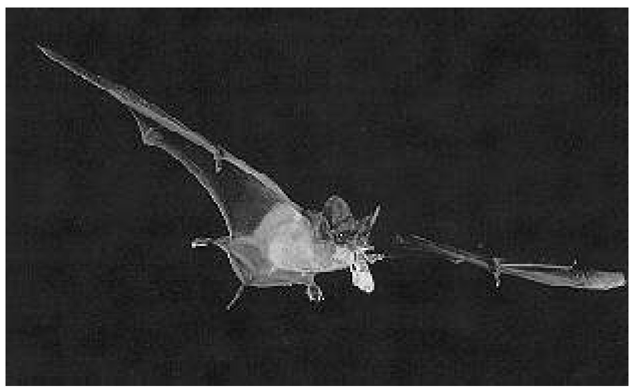
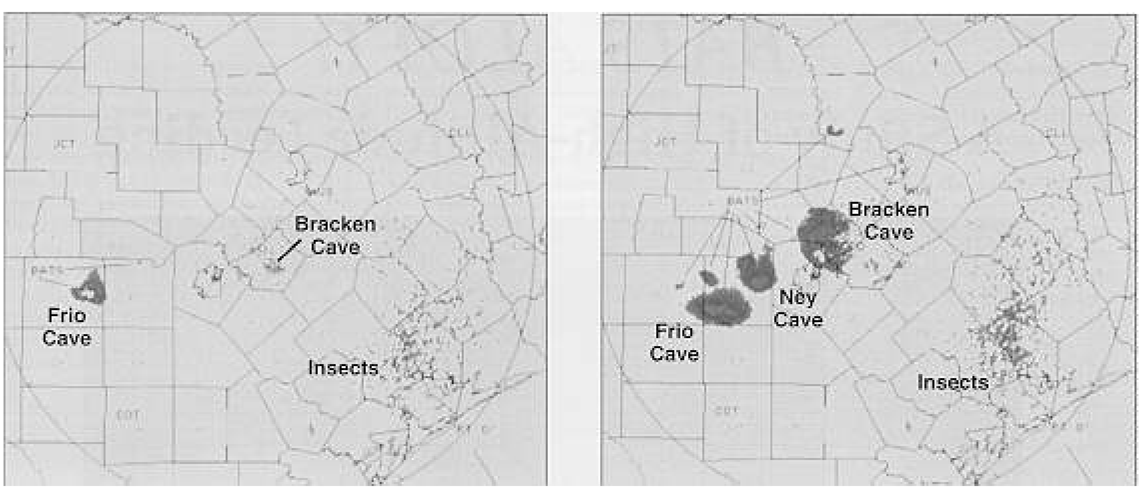
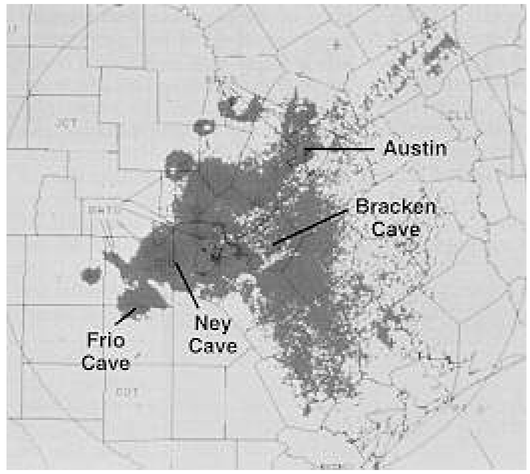


Although we have long known that Mexican free-tailed bats eat large quantities of moths, we are now in the process of determining just how many and which species they consume.





Doppler radar can detect the mass movements of large bat emergences the same way it detects falling rain. These three radar images show the progression of several emergences in Central Texas on the evening of July 7, 1995.

In the image on the left, the large triangular shape shows the bats first beginning to leave Frio Cave. The "doughnut hole" in the center roughly indicates the area around the mouth of the cave, where the radar cannot pick up the lowest flying bats that are just emerging. The scattered spots on the right are caused by large insect populations.

In the middle image, 13 minutes later, several colonies have begun to emerge. The bats from Bracken Cave show up in a doughnut formation. Also apparent is the emergence from nearby Ney Cave, the third largest bat cave in the area.

In the last image, 22 minutes later, other small bat colonies, including the one from Austin's Congress Avenue bridge, have also set out for the night. All the bats are traveling southeast toward the concentrations of insects over croplands.

USDA researchers John Westbrook (center) and Jason Lee (left) help the author (right) prepare to launch a helium-filled balloon called a tetroon. Attached to the tetroon is a tracking device, a bat detector equipped with a radio microphone, and instruments to measure atmospheric conditions.

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