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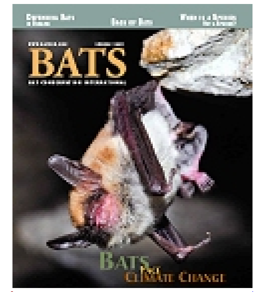

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The Threat of Climate Change
Bat reproduction may suffer in the American West
Rick A. Adams

The Rocky Mountains of Colorado offer a wondrous mosaic of habitats from lowland prairies to treeless alpine tundra. At the 40th parallel near Boulder, the Continental Divide reaches its easternmost point in the United States, producing steep and convoluted relief across which climate and ecology differ dramatically. The abrupt topography compresses habitats and ecotones (the transitions between habitats) into remarkably condensed communities of animals and plants. Thus, ecologists can study a diversity of ecosystems in one local area that is equivalent in scope and richness to that which occurs across the 1,200 miles (2,000 kilometers) between Boulder and the Canadian Arctic. For bats, this remarkable landscape provides for the coexistence of a diverse assemblage of species.

My students at the University of Northern Colorado and I have been conducting research on bat populations in the region for 13 years. This persistence illuminates long-term population trends in this richly varied medley of bats. The underlying questions of our studies have been: (1) do the limited water resources of arid landscapes influence roost-site preferences and reproductive ecology of bats, and (2) does water availability influence how bat populations and communities are structured?

Our research produced a number of unexpected results, especially concerning what appears to be surprisingly complex cooperative behavior, as well as mineral acquisition, maternal-roost clustering and the critical importance of near-roost water sources for milk production by mother bats. After 13 years, we are beginning to stitch together the natural history of the nine resident bat species and the importance of water sources to stability and sustainability of populations.

Unfortunately, our data also strongly suggest a potentially devastating impact of climate change on these bats: increasing regional temperatures, declining precipitation and reduced stream flow appear to negatively influence the ability of females to reproduce.

Upon leaving their high-elevation hibernation sites in late April or early May, bats descend into the food-rich lowlands. Males and females, which hibernated together, break away into bachelor and maternity groups. Females typically return year after year to the same rock-crevice roosts, usually located near small-stream water sources. We consistently find maternity roosts of various species located close to relatively stable but small-scale water features.

Some of these pools are less than six feet (1.8 meters) in diameter, yet they buzz with activity after sunset, as hundreds of bats descend to the surface to drink. They must replenish water lost during their daytime siestas within sun-baked rock crevices where higher roost temperatures help with gestation. Some bats have been shown to lose more than 30 percent of their body mass through evaporative water loss over a single 12-hour roosting cycle. When females are lactating water-rich milk for their young, water loss may even be higher.

The combination of hot, dry roosts, small body size and lactation suggests that reproduction in these female bats is a staggering effort that likely explains why we find maternity colonies of multiple species near reliable pools of water. At dusk, water-stressed females descend to drink soon after emerging from their day roosts, skimming the surface multiple times before leaving the area.

It is not only the crevice-roosting bats that come to drink. At many watering sites, we catch all nine resident species, including less abundant species, such as the hoary bat (Lasiurus cinereus) and silver-haired bat (Lasionycteris noctivagans), that use trees as roosts. Their presence increases the already-high numbers of bats trying to squeeze into these small pools for a drink. Nights following the hottest, driest days correlate with the highest activity levels at water sources, where, at first glance, the scene looks like sheer chaos.

Upon closer examination, however, the apparently lawless free-for-all turns out to have a definite and unexpected order and process. As various species leave their roost sites within minutes of each other, they do not all come to the pool simultaneously. Instead, they arrive in species or colony groups in a specific and predictable order night after night, year after year.

Peaks of activity are distinctive for each species. We confirmed this phenomenon by recording exact capture times of each bat that visited to drink and by compiling data over several years. The pattern was consistent: bats drinking at these small pools are organized by predictable visitation times, without which individual access to the water would be problematic at best.

Even more astonishing, however, is the discovery that the bats actually line up to drink, rather than simply diving in from every direction. The chaos of bats zipping and milling a few feet above the water is completely at odds with what is happening at the surface. Working with Dr. James Simmons of Brown University, we used a thermal-imaging camera to record this amazing behavior at the smallest, most active pools.

All bats that approached for a drink did so singly. Each one came in from a specific direction and followed a drinking pathway â€“ not unlike a landing strip at an airport. Further, the film revealed that bats entering the 'drinking queue' did so by making a wide turn away from other bats above the pool, then circling into the precise approach path. We observed multiple bats entering the drinking path one after the other and following one another across the water's surface in a single-line approach.

While filming in July, when the pups begin to fly, we watched this finely tuned drinking game suddenly break down as some bats caused near-collisions by trying to drink from the "wrong" direction. We can only suppose that these were inexperienced juveniles, perhaps making their first attempt at water-hole etiquette. When this occurred, the bat that was in the correct pathway would call out a distinctive, audible buzz at the wayward intruder. It appears that young bats need to learn the rules of the game from adults.

We have found that female bats apparently can determine the mineral content of drinking water and that they lead their young to pools with higher levels of dissolved calcium, perhaps to help with skeletal development (see "The Lure of Dirt," BATS, Winter 2006). Females benefit from these high-mineral pools because insects provide scant calcium and they typically end up calcium-deficient during their reproductive period. In some cases, we have radiotracked lactating females flying several miles to reach small, inconspicuous but calcium-rich pools hidden in the forest, bypassing more obvious water sources to reach

them. We found no apparent relationship between male bats and these high-calcium drinking opportunities.

But while mineral content may play a role in which pools adult females and their young visit, the proximity of water to maternity roosts is the most critical aspect. We demonstrated this through an experiment in summer 2006. We marked 29 female fringed myotis (Myotis thysanodes) from a maternity colony by inserting a passive integrated transponder â€“ a PIT tag â€“ just beneath the skin of females that were either lactacting or nonreproductive. The tiny tags do not require batteries and can be read by a scanner to identify the individual.

We placed an antenna (the scanner) in a small pool near the roost site to record visitation patterns of bats of known reproductive status. The results were sobering. Lactating females drank at the pool 13 times more often (236 visits) than nonreproductive females (18 visits) over an 11-day period. Lactating females clearly have very high water requirements and having a water source near the maternity colony may be one of the criteria females use in choosing roost sites.

Next, we plotted our 13 years of data against annual weather conditions, including mean monthly high temperature, mean monthly precipitation and mean monthly stream-discharge rates. What we found was disconcerting. In years with warmer, drier conditions, reproductive outcomes dropped precipitously. The long-term trend in the data showed a steady increase in numbers of nonreproductive females captured during such years. In the warmest, driest year of our study, 2007, more than 50 percent of the adult females we captured were nonreproductive â€“ a huge difference from years when weather conditions were closer to average and only 11 to 15 percent of captured females were nonreproductive. Virtually all climate-change models predict warmer and drier summers in this region.

Analyzing the data showed that the availability of water and especially precipitation were most closely correlated to reproductive status. Precipitation, of course, feeds local streams and our data reveal a sudden crash in female reproduction when flow rates of Boulder Creek (the only drainage in our field area that is monitored for flow rates) falls below 247 cubic feet (7 cubic meters) per second. When this large stream falls to such a low flow rate, smaller streams near roost sites may, in fact, be almost completely dry. This sudden crash in reproductively active females implies that there is a threshold of minimum water availability required to support local bat populations. These data, of course, fit well with our PIT-tag study of female reproduction and visitation frequency to water sources.

We often think of bats as highly mobile mammals capable of travelling large distances to forage and find water. Maternity roost sites, however, provide well-established anchors that help support local bat populations over the long term. Females return to these sites year after year to give birth to and raise their young, and females in maternity colonies seem to resist abandoning such areas, even when water resources dwindle. Instead of leaving, females apparently are shutting down â€“ or being forced physiologically to halt â€“ reproductive output that the environment can no longer support. The long-term risk to these populations appears substantial.

Climate change in western North America is expected to increase in coming years, with still-greater reductions in summer precipitation and winter snowpack. Already the loss of accumulated snowpack, combined with spring runoffs that begin up to a month earlier than in the past and reduced summer rainfall, has measurably affected regional patterns of stream flow. Thus, the outlook for future water availability in natural ecosystems is grim.

Climate-change models for the Colorado River Basin predict that for every 0.6-degree F (1-degree C) increase, we can expect 24 percent less snow, 3 percent less summer precipitation and 36 percent less water storage.

If there is one spark of hope in all this, it is that we can begin to mitigate some of these effects by developing management plans that include artificial water sources to support high-risk maternity colonies. Climate change is upon us, and we can do little to stem the tide in the short term, but fast-track solutions to immediate problems may just be enough to avoid a sudden collapse of distressed ecosystems.

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