LOOKING FORWARD

What can we say about the next 20 years of bat conservation and research? Our predictions about the future of science tend to look humorously inaccurate in retrospect. Modern science has produced the internet, genetically engineered food, and human genome sequencing, but not much in the way of interstellar space travel. Our ineptitude in forecasting advances in science and technology is largely due to the fact that scientific research is so opportunistic. Its direction is driven not merely by what progress we want to see, but often by opportunities opened by unforeseen advances in technology. New cohorts of tech-savvy young scientists are continually exploring topics never before possible. In the science of bat research and conservation, new technologies are paving the way to answer some of our biggest questions. By learning more about bats, we can better understand and address threats to their survival and to the roles they play in healthy ecosystems. By looking at the intersection of the most pressing questions and the fastest-growing technologies, we can identify a couple of research avenues that promise great returns.

In the past, biologists studied bat movements by banding many bats and hoping that someone somewhere would catch those same bats. As you can imagine, it wasn’t very efficient. Today, researchers are investigating the patterns of bat movements through a variety of more sophisticated methods. Researchers routinely attach tiny transmitters to bats to track where they fly and roost; and even their temperatures. These transmitters emit pulses of radio waves that allow researchers to triangulate and track their positions, and new models of tracking devices are getting smaller and more advanced. The newest transmitters can communicate with
satellites to reconstruct flight paths of long-range migrations, but these are still too large for most bats.

In an emerging field called “aeroecology,” researchers are using advanced weather radar systems to track movements of both bats and their insect prey without the need to catch them. Researchers are now using data from Doppler radar systems to reconstruct three-dimensional models of millions of Mexican free-tailed bats emerging from caves in Texas, climbing high into the night sky, and consuming millions of migrating moths.

In light of the huge threat posed by wind farms, one of the most pressing questions in bat conservation is clear: Where and when do bats migrate? In the years to come, our knowledge of bat migration will undoubtedly take leaps forward, propelled by continuing advances in tracking technologies.

Bat movements can also be assessed indirectly in some rather ingenious ways. When animals eat, they acquire the atoms from their local environment into their bodies. Since the ratios of stable hydrogen isotopes change with latitude, the stable hydrogen isotope ratios of bat fur can reveal where bats have been traveling and eating. Similarly, since desert plants use different versions of photosynthesis (CAM photosynthesis and C3 carbon fixation), they can produce distinct carbon isotope ratios in their tissues. Researchers have used stable carbon isotope analysis to show that endangered lesser long-nosed bats
rely heavily on agave plants on their migration south and on dense stands of columnar cacti on their way back north.

Stable isotopes are not the only kind of invisible clue available to researchers. Using tissue samples of lesser long-nosed bats caught in only 13 locations, researchers have also described genetic divergence between populations and migration routes by analyzing variation in DNA. The use of such genetic information in ecology studies has exploded in recent years, and what we are seeing is likely only the tip of the iceberg.

CLUES FROM GENES & GENOMES

The realization that huge amounts of ecological information can be obtained from DNA has led to the exploding field of molecular ecology, and in coming decades molecular tools will be increasingly important for bat ecologists. In fact, the fastest growing scientific technology today is DNA sequencing. Since the information for building an organism is written in the DNA code, sequencing fragments of DNA, or even the entire genome of an individual, has the potential to reveal all the biological information that makes an individual or species unique. Tracing changes in the genomes from one population of animals to another allows us to map exactly how they are related to each other on the family tree of all life. As the evolutionary history of bats becomes increasingly clear through molecular techniques, we will have a better understanding of how, why, and where bats evolved and how they are related to all other living things. Studies of gene flow and population genetics can help us identify the populations for which conservation is most critical.

Molecular techniques can also answer more basic ecological questions. For instance, we can use DNA to study kinship, family dynamics, and social lives of bats, or we can sequence the prey DNA in bat guano to see what bats eat. Sequencing the DNA of the pathogenic fungus Geomyces destructans, which causes White-Nose Syndrome, may help us understand where the fungus came from and what makes it so destructive to North American bat populations. The information in DNA is profoundly vast and will only be fully realized by future generations.

A genome is like a code for making an organism, but the information remains largely encrypted. Although we know the information is there, we are still not sure which parts of genomes are meaningful. But comparisons can give us information. By comparing genes and genomes, the evolution of similarities and differences among and within living
species can be identified. In the future, we might be able to "read" genomes in the same way we read the blueprint for an invention. We might be able to predict much about the biology, ecology, even behavior of an unfamiliar organism simply by sequencing the DNA in a speck of tissue. This is the lofty goal of bioinformatics, possibly the fastest growing field of science. Bats have evolved into more than 1,200 species, and possess an extraordinary amount of genetic diversity even within a single species. The next few decades will allow us to explore how and why bats became so successful and speciose.

**Whither the NATURAL HISTORY OF BATS?**

Does this era of modern molecular biology spell doom for organismal biology? Today, natural history, the description of nature, is more likely to grace the pages of popular magazines than of leading scientific journals. Natural history developed into the science of organismal biology, including ornithology, ichthyology, mammalogy, and others. Compared to modern molecular genetics, these taxon-specific fields often seem to be in academic decline, receiving less science funding and less academic attention. Modern biologists have been increasingly turning their attention away from particular species toward genes and ecosystems. As one of my colleagues once put it, "DNA is DNA, I don't always know what the animals even look like." At the same time, the modern conservation movement has also been trending toward a focus on conserving ecosystems, rather than on protecting single species one at a time. This holistic approach is efficient because habitat destruction and anthropogenic changes at the ecosystem level are problems that threaten multiple species. From this perspective, one might wonder why we should focus time and energy specifically on bats. It may seem that by simply protecting habitat, we will be protecting bats alongside other wildlife, and we might not need to know detailed ecological information about the lives of bats.

But this view is naïve. Knowing the natural history of bats is as indispensable as ever to their conservation. The problems of wind turbines and White-Nose Syndrome clearly make this point, because these threats endanger bats specifically. In order to confront such threats, we must possess intimate knowledge about behavior, ecology, and physiology unique to bats. And the bulk of this knowledge is simply lacking. When bat biologists first realized the gravity of the threat that wind turbines posed to migratory bats, we were all but embarrassed to admit to ourselves just how little we knew about bat migration or the
The big brown bat consumes significant numbers of crop and forest pests.

Recent research indicates that some Baja populations of insectivorous pallid bats also take advantage of floral nectar.

population sizes of migratory bats. Where did different bats migrate? How many were there? How far did they go? What paths did they take? These and other basic questions must be addressed by researchers in the coming years. Similarly, white-nose syndrome was discovered as early as it was thanks to the work of bat biologists who actively monitored caves and mines where bats hibernate. There's simply no replacement for careful observations of the natural world.

One obvious lesson we can take from these recent threats to bat conservation is that organismal biology and species-specific natural history are absolutely essential for conservation. Only a few years ago, I would have written that the future of bat conservation in North America lies in protection of habitats and ecosystems. No one expected the White-Nose Syndrome population crash or the mortality effect of wind turbines. Few scientists or conservationists expected that detailed information about the immune systems or migration patterns of particular bat species would become so immediately and extraordinarily crucial to their conservation.

General conservation and ecology is not enough. We need to know more about the natural history of most of the North American bats. To save bats, we need people who call themselves bat biologists. Not all the most important questions can be solved quickly with the latest technologies; sometimes solutions are best acquired through years of rigorous fieldwork. Gathering important ecological data or observing natural behaviors often requires long days over continuous months in the field. But the experience is rewarding, and the results can be illuminating.

Ecological fieldwork is still crucial for determining what role bats play in a healthy ecosystem and how important bats are for producing the essential resources people derive from natural communities. For example, experiments on bat pollination have shown that bats are generally more effective pollinators of plants per visit than bees or birds. In fact, plants once pollinated by birds have more often evolved to become bat-pollinated than vice versa. However, in many areas, desert plants adapted for bat pollination now rely increasingly on suboptimal insect or bird pollinators simply because the bats have become too scarce. Other plants that are tightly coevolved with bats will not be able to adapt so quickly to the local loss of bat populations. The fate of bat pollinators and many of their desert plant allies are intertwined: a threat to one poses a threat to the other. Other recent ecological studies have shown the importance of bats in reducing insect
pests (up to 84 percent in Mexican coffee plantations). In 2011, a report in the journal Science suggested that the insect-control services of bats were worth roughly $23 billion each year to agriculture. In most cases, the ecological importance of bats is vaguely known, but not well documented. Further ecological studies documenting the importance of bats will be vital to their conservation.

Given their huge diversity, great abundance, and wide-ranging distribution, as well as the critical roles they play in ecosystems and in our own well-being, bats will no doubt continue to be the focus of many scientists around the world. This particular field continues to grow and attract some of our brightest young minds. Many more questions remain than can be answered with the current workforce. Luckily, searching for the answers is exciting, and finding them holds promise for a better world for humans and for bats.

SUGGESTED READINGS ON BATS


