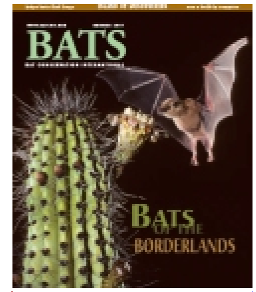
VOLUME 25, NO. 2 Summer 2007



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Magnetic Bats
Finding their way with a biological compass
Richard Holland

Bats are uniquely suited to their nocturnal life in the skies. In addition to vision, they examine the world through echolocation, dodging obstacles and capturing insects on the wing at high speed. This short-range sonar sends sound waves into the darkness and analyzes the echoes that bounce back from anything in their path. Now our research adds to the impressive array of biological tools that bats use to navigate in the dark: They seem to rely on a magnetic compass to find their way.

Bats are among many animals that have particles of a magnetic iron oxide called magnetite in their bodies. Magnetite â€“ confirmed in bats, butterflies, salamanders, dolphins, honeybees, birds (including homing pigeons), humans and others â€“ is often proposed as a source of direction-finding abilities. The mechanism by which it operates is unclear.

Our experiments at Princeton University in New Jersey demonstrated that artificially shifting the Earthâ€™s magnetic field alters the homing behavior of big brown bats (*Eptesicus fuscus*) in generally predictable ways, indicating that these bats use an internal magnetic compass of some kind to navigate at a distance.

My colleagues in this study included Kasper Thorup of the Zoological Museum and Center for Macroecology at the University of Copenhagen (Denmark); Maarten Vonhof of Western Michigan University; William Cochran of the Illinois Natural History Survey; and Martin Wikelski of Princeton University.

Bats leave their roosts each evening and spend much of the night hunting prey. While big brown bats might restrict their foraging to a few miles, species such as the Mexican free-tailed bat (Tadarida brasiliensis) can range 50 miles (80 kilometers) or more. In addition, many bats are migratory. Most species travel less than 300 miles (480 kilometers) between summer and winter habitat, although a few migrate more than 1,000 miles (1,600 kilometers).

The big brown bats we studied fly relatively short distances but seem to use the same mechanism as migratory birds that fly across continents. We captured big browns on various nights at their roost in a barn at a Princeton University field station and kept them overnight.

Ten bats were exposed to artificial magnetic fields. Each bat was confined in a transparent container and placed inside a device called a Helmholtz coil, which produces a uniform magnetic field. The bats were exposed to the field for 45 minutes before sunset and 45 minutes after, and they had a clear view of the setting sun and the horizon during this time. For five of the test bats, the magnetic field was shifted clockwise by 90 degrees with respect to the magnetic north pole; for the other five, it was shifted counterclockwise. A control group of five bats was not exposed to any non-natural magnetic field.

We took each bat, individually and on separate nights (with two exceptions), 12 miles (20 kilometers) north of their home roost, attached a tiny radio transmitter and released it. The bats were tracked by radio receivers aboard a small aircraft flown by Wikelski until they either returned to the roost or stopped moving for more than one hour.

The five control bats, relying on the natural magnetic field, correctly headed south and easily found their way home â€“ demonstrating a predictable homing response to which the test bats could be compared.

Bats exposed to the artificial fields took off in wrong directions. Those exposed to the

counterclockwise magnetic field flew west, while those that experienced a clockwise field flew east. In other words, they flew in the direction that should have been south on the basis of the magnetic field they experienced at sunset. This behavior strongly indicates the bats were using an internal magnetic compass that was calibrated at sunset.

The story, however, seems a bit more complex than that. Five of the misdirected bats were unable to find their home roost (and we retrieved them). The other five test bats, however, somehow realized they were off track and figured out how to make it back home. They either recalibrated their internal compass or used some other cues to correct their navigation.

Such course corrections have not been reported previously in bats, although homing pigeons can identify and correct induced errors in their flight direction.

More research is needed to better understand the details of how bats and many other wide-ranging animals find their way across landscapes near and far. The radiotelemetry signals collected aboard aircraft in this study could also be sent to low-orbiting satellites â€“ a possibility that could open new vistas for field research.

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