Stars and inner compass guide moths and birds, say researchers

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Understanding how migratory birds and moths use Earth's magnetic field could aid conservation. Credit: CC0 via Unsplash

Gray-brown bogong moths may not be much to look at, but every year they perform a nocturnal journey worthy of attention. Billions of them fly as many as 1,000 kilometers from plains in eastern Australia to mountain caves to escape the summer heat.

Arriving in late September from their breeding grounds, up to 17,000 moths pack each square meter of cave wall and lie in a dormant state in a southeast mountain range known as the Australian Alps.

Extra sense

"It usually looks like the scales of a fish if you go into these caves during the summer," said Professor Eric Warrant, a biologist at Lund University in Sweden. "It's absolutely amazing."

In autumn, the moths fly back to mate, lay eggs and die. Their progeny repeat the voyage without any experience of it—a feat that has long puzzled researchers.

While it has been known that insects, birds, turtles and fish can navigate using the Earth's magnetic field, the specific mechanisms employed to activate this "sixth sense" have remained mysterious. So too has the connection with other potential sensory cues.

Greater knowledge in this area could bolster conservation efforts and help stem widespread losses in biodiversity amid warnings from scientists that the world is facing a sixth mass extinction.

In 2019, the bogong-moth population suffered a 99.5% collapse as a result of drought. Although the numbers have risen since, they're still well down compared with before.

Crucial species

The moths are crucial for plant life that they pollinate and for wildlife that depends on them for food. One such animal is the critically endangered mountain pygmy possum.

"The bogong month is a keystone species in the alpine ecosystem, so their survival is critical," said Warrant.

He led a project to uncover some of the secrets of the bogong moths' navigating abilities. Called MagneticMoth, the project ended in August 2023 after six years.

Warrant's team tethered migrating bogong moths in an outdoor flight simulator. In doing so, the researchers confirmed that the moths did indeed use the Earth's magnetic field to navigate.

The next task was to find out how the moths do this and where the mechanisms responsible are located.

The team investigated molecules called cryptochromes. In birds, evidence suggests that cryptochrome in the eyes may enable them to "see" magnetic fields.

While the project's genetic analysis has yet to yield final results, Warrant believes they will prove that cryptochromes are responsible for magnetic sensing in bogong moths.

Starry surprise

The team also made discoveries that took matters in new directions.

"We found out a few other things that I think are actually even more exciting than this sensing," said Warrant.

One is that bogong moths use the stars—in addition to the Earth's magnetic field—to navigate. In the laboratory, their brain cells responded to the rotation of a projected night sky.

Warrant said the ability to use night-sky cues to navigate in a specific compass direction was previously known only in humans and in some species of nocturnally migrating birds. The moths possess it while having a much smaller head.

"The moths seem able to travel in their inherited migratory direction under a starry night sky even if we remove Earth's magnetic field," Warrant said. "If you have this tiny insect with a brain a tenth the volume of a grain of rice and eyes smaller than a pinhead, that they can do this is surprising."

The finding suggests bogong moths may also be using a "hierarchy" of cues to navigate, with the ability to rely on different ones when others aren't available. Pending further research, Warrant suspects the stars may even be the dominant cue.

Quantum ideas

Understanding how migratory birds use Earth's magnetic field has also been a challenge with implication for conservation efforts.

That's partly because the magnetic interactions at play have seemed too weak to trigger the required chemical reactions.

But attention is now turning to one possible explanation: atomic and subatomic "quantum" scales, at which behavior of matter doesn't follow typical rules.

"There's a quantum-mechanical mechanism by which such weak magnetic interactions can affect chemistry," said Professor Peter Hore, a chemist at the University of Oxford in the UK.

He's pursuing this avenue as co-coordinator of a project called

QuantumBirds. It runs for six years until the end of March 2025.

Blue light

As with bogong moths, the focus is on cryptochromes serving as a compass for birds to navigate during migration.

Derived from the Greek for "hidden color," cryptochromes are molecules sensitive to blue light in certain animals and thought to be involved in magnetic-field sensing in a number of species.

"Migratory birds have at least six different cryptochromes in their eyes," said Hore. "We needed to work out which was most likely to have a magnetic-sensing function."

The team settled on a candidate called cryptochrome 4a—Cry4a—for several reasons including changing levels of the protein in night-migratory European robins.

"Cryptochrome 4a shows a seasonal variation, with higher levels in the spring and autumn," said Hore. "That would be consistent with migration."

With Cry4a in lab cultures, the QuantumBirds team found evidence that the molecule was indeed magnetically sensitive—and more so than the same proteins in non-migratory pigeons and chickens.

While testing Cry4a in live robins would be needed to confirm this as the mechanism, the results are promising, according to Hore.

"This cryptochrome seems to have the right properties to be the basis of the birds' magnetic compass," he said.

Homing instinct

Understanding how migratory birds navigate could be key to future conservation, particularly given that it is difficult to relocate them because of an instinct they have to fly back to their habitat, according to Hore.

"If we could understand the mechanisms they use to navigate, maybe we could fool them into thinking they want to stay where we've put them," he said.

For his part, Warrant at Lund University said greater knowledge about how creatures including bogong moths navigate could lead to the development of alternative navigation systems to GPS for people to use.

Understanding the homing instincts of moths—coupled with the pivotal role that they play in the ecosystem—is yet another reason to ensure their protection.

"Raising awareness that even a humble insect is worth saving is an important step in the right direction," Warrant said.

More information:

- MagneticMoth
- QuantumBirds

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