Insect trapped in amber reveals the evolutionary battles of ancient Europe

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Artist's concept of ancient katydid trapped in amber. Credit: Charlie Woodrow

An extraordinary insect preserved in amber is opening our ears to a world of communication beyond our hearing. New research on an extinct katydid in the Natural History Museum's collection reveals that katydids have been using ultrasounds for millions of years to try and avoid predators hearing them.

The song and hearing range of the cricket-like insect has been discovered tens of millions of years after its death.

After being trapped in amber for 44 million years, new scans of Eomortoniellus handlirschi have allowed scientists to reconstruct the katydid's mating call. It reveals the earliest known animal to communicate at frequencies far beyond the range of human hearing.

While not quite as high as some living katydids, its call's pitch would have been above the hearing of most mammals. Only a select group of mammals, including the first bats, were tuning into its call, as part of the opening salvos of an evolutionary arms race which continues today.

Dr. Charlie Woodrow, the lead author of the new study, says, "This katydid was frozen in time at a crucial moment in the arms race between echolocating predators and insects."

"Shortly before this animal was fossilized, bats had developed the ability to echolocate, which may have driven the katydids to call at higher frequencies. At the same time, their ears were adapting to listen out for bats trying to hunt them down."

"This discovery wouldn't have been possible without such a well-preserved katydid, which highlights how important museum collections are in discovering specimens like these."

Professor Fernando Montealegre-Zapata, who co-authored the new study, adds, "I've planned to study ear development and evolution in katydids for a long time, but it's very rare to find a fossilized katydid preserved this well."

"A colleague told me I was dreaming when I told him that I wanted to find a fossil like this, so to find this specimen was very lucky."

The findings of the study were published in the journal *Current Biology*.

Bats vs. katydids: An evolutionary battle

Hundreds of millions of years ago, katydids were among the first animals to take advantage of using sound to communicate. They started to make noise by scraping their wings together, with the earliest evidence for this dating back more than 240 million years.

These sounds are generally made by males, which use them to attract females. However, these calls can also attract the wrong kind of attention, in the form of predators looking for a meal.

This might explain why, over millions of years, katydids developed the ability to call at increasingly higher frequencies. But by 125 million years ago, the hearing of the katydid's mammalian predators had caught up with its calling.

This led some katydids to produce ultrasonic sounds with even higher pitches, which wouldn't have been heard until the first bats evolved around 52 million years ago.

From this point on, bats and katydids have been stuck in an evolutionary arms race. Bats have been evolving to be better at hearing the calls of katydids, while the insects have changed their calls and behavior.

"While katydids were likely already exploring high frequencies, both to avoid eavesdropping and to develop a greater diversity of signals, bats gave them a new impetus," Fernando explains.

"It might seem strange that katydids kept singing at these high pitches once they could be overheard, but ultrasound dissipates quickly in the environment. This ensures that a distant bat can't hear the singing katydid as the sound will break up before it can be heard."

Just as this arms race was heating up 44 million years ago, a katydid landed on a pine tree and been quickly overwhelmed by sticky resin flowing down the trunk. As it struggled to free itself, the sap coated its entire body and hardened.

The hardened resin then dropped to the floor of the forest and over millions of years began to transform into amber. At some point, this amber was swept into a lagoon and buried in sediment, eventually being uncovered in 1936 in what was then East Prussia—an area now split between Poland, Russia and Lithuania.

After being described as a new species, the specimen of E. handlirschi has sat in the collections of the Natural History Museum for over 80 years. With the development of better scanning technology, researchers have now been able to peer inside the amber and reveal the katydid's long held secrets.

An extraordinary Eocene ear

Unlike in mammals, the ear of a katydid is actually located inside its legs, which makes it vulnerable to being crushed during fossilization. But CT scans of the katydid revealed that the sap had got into the katydid's ear canal.

With the sap inside, the delicate structure of the insect ear was preserved.

"It's really difficult to find these insects preserved in amber," Charlie says. "The ears are only fully developed in adults, but fully-grown katydids are normally big enough that they won't get caught in amber."

"It's lucky that Eomortoniellus handlirschi is a really small species, which means it could get stuck so that we could investigate it all this time later."

To find out what it was best at hearing, Charlie teamed up with colleague Dr. Emine Celiker to create models of how sound travels in the ears. They calculated that the katydid was probably best at hearing sounds of around 30kHz.

At the same time, they also used knowledge of how living katydids produce sound to predict the frequency of the call E. handlirschi produced. It appears that its call was at a similar frequency to that which it could hear, suggesting the insects were using the sounds to communicate.

The team also found two other peaks in the katydid's hearing at around 60 and 90kHz. But rather than being related to communication, this is likely to have helped the insects eavesdrop on the echolocation calls of early bats and avoid becoming their dinner.

The ability of the insects to listen to high frequencies would have been enhanced by the katydid's pinnae, which in mammals is the earlobe. While only partly developed in E. handlirschi, evolution in the years after it was trapped in amber has allowed its relatives to listen to calls of over 100kHz.

"It's now important to identify more fossils to track these changes," Charlie says. "I think that more adults of this species, or its close relatives, will turn up as many are sold online to private amber collections."

"I think it's likely there are more held in public collection as well. It just takes the right people to notice it and study it."

More information: Charlie Woodrow et al, An Eocene insect could hear conspecific ultrasounds and bat echolocation, *Current Biology* (2023). DOI: 10.1016/j.cub.2023.10.040

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