Secrets of the cicada's sound

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Of all the bugs that achieve the mantle of summer pest, cicadas are perhaps the most curious. They don't sting, they don't bite, they don't buzz around your head, they taste good in chocolate, but as the drowning din of the 17-year brood this summer will remind: we would love them less if they emerged more often.

Cicadas are unique among insects in their ability to emit loud and annoying sounds. So why would anyone actually want to replicate theses sounds?

A team of U.S. Naval researchers have been working on that very problem for several years now, because it turns out that the humble cicada has naturally solved a compelling unmet challenge in underwater communication: how to make an extremely loud noise with a very small body using very little power.

At the 21st International Congress on Acoustics (ICA 2013), held June 2-7 in Montreal, the team, based at the Naval Undersea Warfare Center (NUWC) in Newport, RI, will present their latest results analyzing the cicada's sound – first steps toward making devices that would mimic it for remote sensing underwater, ship-to-ship communications, rescue operations and other applications.

How Cicadas Make Their Sound

Humans have marveled at the periodic emergence of cicadas for thousands of years, and as far back as the 1940s, scientists have tried to

uncover the secrets of this strange insect. But only recently has it been possible to carefully measure the physical properties of the cicada using lasers to simultaneously measure the vibration of its "tymbals," the corrugated exoskeleton on the insect responsible for its sound, explained Derke Hughes, a researcher at the Naval Undersea Warfare Center.

Hughes works on an unfunded project to uncover the insect's secrets in his spare time, collaborating with other volunteers. In Montreal, Hughes and his colleagues will present work on the nonlinear nature of cicada mating calls.

Their analysis shows is that the insects manage to produce their incredibly large sound because they have a unique anatomy that combines a ribbed membrane on the torso that vibrates when they deform their bodies.

While that basic insight is clear, the problem of reproducing the sound is still daunting, Hughes said. He has not yet worked out an accurate physics-based model that describes how the cicada makes its sound when it deforms its body. "We're still working on it," he said.

A second talk in Montreal will describe an attempt to give a fuller physical explanation of how the cicada generates sound. The explanation, in brief, is that a buckling rib is arrested in its rapid motion by impact with the part of the cicada's anatomy called a tymbal, which functions somewhat as a gong being hit by a hammer. It is set into vibration at nearly a single frequency, and the vibration rapidly dies out.

Like Buckling All Your Ribs at Once

To understand how the cicada makes its sound, you would have to imagine pulling your ribs to the point of buckling collapse, releasing them and then repeating that cycle, said Hughes.

If your body were like that of a cicada, he explained, you would have a thick set of muscles on either side of your torso that would allow you to cave in your chest so far that all your ribs would buckle inward one at a time into a deformed position. Releasing the muscle would allow your ribs to snap back to their regular shape and then pulling the muscle again would repeat this. The cicada repeats this cycle for its left and right sides about 300 to 400 times a second.

"That's basically what's happening in the cicada," Hughes said.

Replicating this sound is a challenge because the cicada's chirp is nonlinear – it is not a simple matter of one part moving and the sound emerging from that. The buckling is not a uniform process, and the tymbal surfaces vibrate out of phase with each other and then somehow combine to make a sound that can drown out even the noisiest summer barbecues.

Why Cicadas Make Noise

The cause for all that chirping is nature's oldest, Hughes said. Cicada males make sounds to attract nearby females, who respond by snapping their wings. The male hears this and responds to by moving closer.

A few years ago Hughes and his colleagues showed that as the male cicada approaches the female, its sound gets softer. Hughes described this as the cicada putting on its best bedroom voice and uttering the insect equivalent of "hey, baby."

In field experiments, he and his colleagues showed that they could trick the male cicada by making a snapping sound that mimics the female.

More information: The presentations 1pAB11 and 1pAB10, "Nature of nonlinear mechanisms in the generation and propagation of sound in

the cicada mating call" and "Buckling as a source of sound, with application to the modeling of cicada sound generation," are in the afternoon session of Monday, June 3. Abstracts: asa.aip.org/web2/asa/abstracts … ch.jun13/asa151.html and asa.aip.org/web2/asa/abstracts … ch.jun13/asa150.html

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