# Mantis shrimp clubs filter sound to mitigate damage

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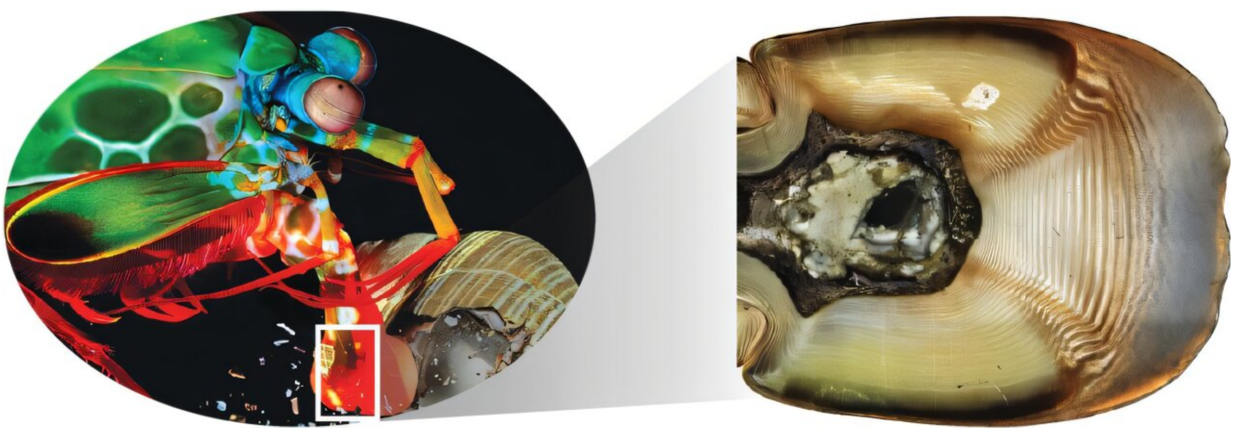

Credit: Horacio Espinosa / Northwestern University

Known for their powerful punch, mantis shrimp can smash a shell with the force of a .22 caliber bullet. Yet, amazingly, these tough critters remain intact despite the intense shockwaves created by their own strikes.

Northwestern University researchers have discovered how mantis shrimp remain impervious to their own punches. Their fists, or dactyl clubs, are covered in layered patterns, which selectively filter out sound. By blocking specific vibrations, the patterns act like a shield against self-generated shockwaves.

The team's study is published today in the journal *Science*.

The findings could someday be applied to developing synthetic, sound-filtering materials for protective gear as well as inspire new approaches to reducing blast-related injuries in military and sports.

"The mantis shrimp is known for its incredibly powerful strike, which can break mollusk shells and even crack aquarium glass," said Northwestern's Horacio D. Espinosa, the study's co-corresponding author.

"However, to repeatedly execute these high-impact strikes, the mantis shrimp's dactyl club must have a robust protection mechanism to prevent self-damage. Most prior work has focused on the club's toughness and crack resistance, treating the structure as a toughened impact shield. We found it uses phononic mechanisms—structures that selectively filter stress waves. This enables the shrimp to preserve its striking ability over multiple impacts and prevent soft tissue damage."

A mantis shrimp shows its dactyl clubs (in greenish yellow). Credit: Andy Law

## A devastating blow

Living in shallow, tropical waters, mantis shrimp are armed with one hammer-like dactyl club on each side of its body. These clubs store energy in elastic, spring-like structures, which are held in place by latch-like tendons. When the latch is released, the stored energy, too, is released—propelling the club forward with explosive force.

With a single blow, mantis shrimp can slaughter prey or defend their territory from interloping competitors. As the punch rips through surrounding water, it creates a low-pressure zone behind it, causing a bubble to form.

"When the mantis shrimp strikes, the impact generates pressure waves onto its target," Espinosa said. "It also creates bubbles, which rapidly collapse to produce shockwaves in the megahertz range. The collapse of these bubbles releases intense bursts of energy, which travel through the shrimp's club. This secondary shockwave effect, along with the initial impact force, makes the mantis shrimp's strike even more devastating."

## Protective patterns

Surprisingly, this force does not damage the shrimp's delicate nerves and tissues, which are encased within its armor.

To investigate this phenomenon, Espinosa and colleagues used two advanced techniques to examine the mantis shrimp's armor in fine detail. First, they applied transient grating spectroscopy, a laser-based method that analyzes how stress waves propagate through materials. Second, they employed picosecond laser ultrasonics, which provide further insights into the armor's microstructure.

Their experiments revealed two distinct regions—each engineered for a specific function—within the mantis shrimp's club. The impact region, responsible for delivering crushing blows, consists of mineralized fibers arranged in a herringbone pattern, giving it resistance to failure. Beneath this layer, the periodic region features twisted, corkscrew-like fiber bundles. These bundles form a Bouligand structure, a layered arrangement, in which each layer is progressively rotated relative to its neighbors.

While the herringbone pattern reinforces the club against fractures, the corkscrew arrangement governs how stress waves travel through the structure. This intricate design acts as a phononic shield, selectively filtering high-frequency stress waves to prevent damaging vibrations from propagating back into the shrimp's arm and body.

"The periodic region plays a crucial role in selectively filtering out high-frequency shear waves, which are particularly damaging to biological tissues" Espinosa said. "This effectively shields the shrimp from damaging stress waves caused by the direct impact and bubble collapse."

In this study, the researchers analyzed 2D simulations of wave behavior. Espinosa said 3D simulations are needed to fully understand the club's complex structure.

"Future research should focus on more complex 3D simulations to fully capture how the club's structure interacts with shockwaves," Espinosa said. "Additionally, designing aquatic experiments with state-of-the-art instrumentation would allow us to investigate how phononic properties function in submerged conditions."

**More information:** N. A. Alderete et al, Does the mantis shrimp pack a phononic shield?, *Science* (2025). DOI: 10.1126/science.adq7100

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