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Inside JEB

MUSCLE POWERS SOME SPEARING MANTIS SHRIMP ATTACKS

Roy Caldwell

A hungry mantis shrimp may be the last thing that a passing fish sees before it is snatched from the water by the predator. Maya deVries, from the University of California, Berkeley, says 'Spearer mantis shrimps stay in their sandy burrows and they wait for a fast-moving prey item to come by, but then they come out of nowhere and grab the prey with their long skinny appendages.' However, little was known about how these vicious predators unleash their lightning-fast attacks. According to deVries, the spearing shrimp are closely related to smasher mantis shrimps, which pulverise the shells of crustaceans and molluscs with a single explosive blow from their mighty claws. Having decided to find out how spearers unleash their deadly assaults (p. 4374), deVries says, 'We thought that they would be just as fast – if not faster – than the smashers because they have a smaller time window in which to capture their prey.'

Working with her PhD advisor, Sheila Patek, deVries took a short trip along the corridor to Roy Caldwell's lab to film some of his *Lysiosquillina maculata* mantis shrimps. Coaxing the nocturnal lobster-sized crustaceans to assault frozen prawns, deVries recalls that the animals were reluctant to attack; 'They probably didn't like the bright lights', she says. However, when the duo analysed the speed of the strikes, they were surprised that the spearer's harpoon speed was much slower than that of their smashing cousin's. Explaining that smashers can unleash strikes at speeds ranging from 10 to 23 m s^{-1}, the duo were taken aback that *L. maculata* could only muster 2–3 m s^{-1}.

Knowing that smasher mantis shrimps store catapult energy in skeletal springs that they unleash during a deadly assault, deVries analysed the trajectories of several *L. maculata* claws in action, and realised that the hefty crustaceans were not using the same mechanism. 'The spear has all the same components [as the smashers]', explains deVries, but she adds that the shape of some of the structures are subtly different and the spring did not deform to store energy prior to an attack – possibly because it is too stiff – preventing *L. maculata* from firing a ballistic attack. 'If the *L. maculata* movement is similar to other ambush predators that have muscle-driven strikes, it is possible that these guys are creating strikes with muscle movement', says deVries.

Next, deVries and Patek tested the reactions of another, smaller mantis shrimp, *Alachosquilla vicina*, to find out whether all spearing mantis shrimps have opted for muscle-powered strikes. Elizabeth Murphy filmed the animals snapping up brine shrimp however, it was obvious that the diminutive crustaceans were using a spring-loaded catapult to spear their nimble prey. The team could clearly see energy-storing deformations in the spring structure before the mantis shrimp unfurled their deadly assaults at 6 m s^{-1}.

But the team were still puzzled by *L. maculata*'s sluggish performance. Maybe the lab-based animals had become too unfit to produce explosive attacks? Traveling to Australia to film *L. maculata* hunting in the wild, the team were relieved to see that the animals' reactions were well within the range of speeds that they had measured in the lab. Adult *L. maculata* use muscle-powered attacks all the time.

Having confirmed that it is possible for the large shrimp to produce lightening-fast strikes without using a spring mechanism, deVries says 'We're trying to get more *L. maculata* in the lab to look at the complete size range in one species to see how the strike scales and to find out if there is a size threshold above which you can't have a spring-loaded strike anymore.'

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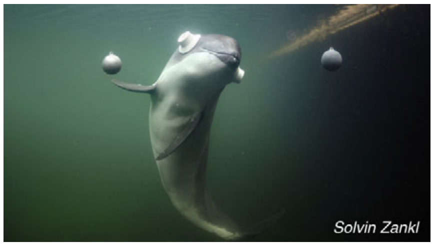
deVries, M. S., Murphy, E. A. K. and Patek, S. N. (2012). Strike mechanics of an ambush predator: the spearing mantis shrimp. *J. Exp. Biol.* **215**, 4374-4384.

Kathryn Knight

PORPOISES ADJUST CLICKS TO GAZE

Gazing into the distance, we adjust our focus and unconsciously scan our eyes back and forth across objects that capture our attention. So what do echolocating animals do when performing the acoustic equivalent? Explaining that echolocating porpoises produce intermittent echolocation clicks – listening for the reflection before clicking again – Danuta Wisniewska from Aarhus University, Denmark, adds that stationary porpoises can adjust the depth of their 'acoustic gaze' by decreasing the click rate as the target is moved farther away and



increasing the volume. In other words, they can adjust their gaze by matching the click rate and volume to the distance from an object. However, echolocating animals are rarely stationary in the wild, 'So I thought it would be an interesting problem to see how the animals use their echolocation while performing a more natural task', Wisniewska says. Fortunately, Aarhus is just a two hour drive from the Fjord&Bælt centre, home to three trained porpoises – Freja, Eigil and Sif – who are old hands at working with research scientists, so Wisniewska and her colleagues Kristian Beedholm, Magnus Wahlberg and Peter Madsen travelled to the aquarium to find out whether the moving animals adjust their click rate and volume to match their acoustic gaze to their distance from objects (p. 4358).

'The nice thing about Fjord&Bælt is that the porpoises live in a rich natural environment, so they have maintained their echolocation', explains Wisniewska. The Fjord&Bælt trainers patiently taught each of the porpoises to approach and recognise an aluminium sphere suspended in the water with their eyes covered. Then the team trained the blindfolded animals to distinguish between the submerged aluminium sphere and another sphere (made from Plexiglas, PVC, brass or steel), with stainless steel the most difficult to distinguish because of the similarity in density to aluminium.

Once the porpoises were comfortable with the task, Wisniewska began recording their echolocation clicks to discover whether the porpoises directed their gaze and matched the volume and click rate to their distance from the target object. Positioning two small hydrophones just above each of the spheres to record the incoming echolocation clicks, the team also attached a digital tag – designed by Mark Johnson – to the back of each porpoise to record the acoustic reflections. In addition, they filmed the porpoises so that they knew the animals' locations at all times to allow Wisniewska to estimate the distance of the animals to the targets.

After painstakingly synchronising all three systems, Wisniewska eventually recorded 95 successful trials. When she analysed the click rates and volumes, Wisniewska could see that the animals were controlling the direction of their echolocation beams and the acoustic gaze with high precision. Scanning the acoustic beam back and forth across the two spheres as they approached, the porpoises accurately adjusted the click rate and volume to match their gaze to their distance from the targets before switching to a continual buzz of clicks during the final moments as they closed in on, and correctly identified, the aluminium sphere.

However, the porpoises didn't always get it right. Wisniewska explains that on some occasions, the animals mistook the sphere made from one of the other materials for the target aluminium sphere. However, having realised its mistake at the final moment, the porpoise was able to swiftly turn its gaze back to the aluminium sphere, instantly selecting the correct click rate for that distance. 'They remember where the object is, they use spatial memory and they control the click rate to match their gaze to the distance from the object', explains Wisniewska.

10.1242/jeb.082768

Wisniewska, D. M., Johnson, M., Beedholm, K., Wahlberg, M. and Madsen, P. T. (2012). Acoustic gaze adjustments during active target selection in echolocating porpoises. *J. Exp. Biol.* **215**, 4358-4373.

Kathryn Knight

CLICKING AND DIVING TIGER MOTHS EVADE HUNGRY BATS

Aaron Corcoran has had quite a few sleepless nights. The behavioural ecologist from Wake Forest University, North Carolina, has devised a setup to study the nocturnal battles between bats and moths in the wild, which involves recording moths' evasive manoeuvres in the early morning hours. Working with William Conner, he wanted to find out just how moths achieve a great escape (p. 4278).

In 2009, Corcoran and his colleagues first reported that tiger moths can jam bat sonar. 'Tiger moths have sound-producing organs called tymbals, which produce ultrasonic clicks that disrupt bats' echolocation, distorting the bat's perception of where the moth is', explains Corcoran. Having demonstrated sonar jamming in captive tethered moths, he was keen to test tiger moth escapology in a natural setting. To do this, Corcoran needed to find a way to follow individual free-flying bats and moths, record their sounds and capture split-second attack sequences on video. Working at the Southwestern Research Station in Arizona, he set up a 200 m^3 observation area with high-speed video cameras to film the animals, ultrasonic microphones to record their calls and clicks, and UV lights on poles to attract the moths. To follow individual animals and create 3-D reconstructions of their flight trajectories, he used a specialised computer package to calibrate the cameras. But even with this advanced technology, Corcoran admits it was painstaking work. 'It took 3 years to get to the point where we could start collecting data', he says.

First, Corcoran tested how effective sonar jamming is in the wild. He recorded encounters between bats and individual tiger moths – either tracked by eye from a release platform or identified by their distinctive clicks on the audio recording – and noted how many of the insects were captured and eaten. Then he silenced some tiger moths by puncturing their sound-producing organs, and released them to see how they would fare. He found that silenced moths were 10 times more likely to be caught by a bat than their clicking counterparts. 'Sonar jamming is extremely effective', concludes Corcoran.

When he took a close look at the 3-D flight paths, he realised that moths also rely on two distinct evasive manoeuvres: diving and rapid fly-aways. 'The most effective defence was clicking and diving at the same time', says Corcoran, adding 'Moths that did this always got away. It was too difficult for the bats to deal with sonar jamming while recalculating their flight trajectory to intercept a dive.' But he was surprised to see that fly-aways were a last-ditch effort. He had reasoned that, since moths can hear bats' echolocation calls from quite a distance, they would fly away sooner. 'Perhaps having the security of the jamming defence allows tiger moths to get on with foraging and finding mates and waste less time avoiding predators', he suggests.

By measuring how successful different bat species were at catching their dinner in the field and in the lab, Corcoran was also able to conclude that sonar jamming is effective regardless of how well bats can fly or the echolocation frequencies they use. 'This is pretty impressive,' he says, 'considering that moths are tone deaf and can't tailor their jamming defence to the predator.'

10.1242/jeb.082784

Corcoran, A. J. and Conner, W. E. (2012). Sonar jamming in the field: effectiveness and behavior of a unique prey defense. *J. Exp. Biol.* **215**, 4278-4287.

Yfke Hager