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INSIDE JEB

Oystershell amplifies pearlfish calls

Onuxondon in a respirometer. Photo credit: Eric Parmentier.

The sea is not always as silent as you might think. A great deal of fish chatter goes on beneath the waves on coral reefs. And when you choose to make your home in a clam or pearl shell, acoustic communication becomes even more imperative. Loic Kéver and colleagues explain that four species of Carapidae take up lodgings in the shells of molluscs and one member of the family, *Onuxodon fowleri*, makes its home in the shells of black-lip pearl oysters. Explaining that most Carapidae are capable of producing sound by vibrating their swimbladders, Kéver and his colleagues were curious to find out whether *Onuxodon* could also produce sound and if so, could the sounds be heard beyond the fish's shell homes (p. 4283).

Kéver recalls that finding the elusive animals was not easy. 'Eric Parmentier had tried to find them in many islands,' says Kéver. However, Franck Lerouvreur eventually succeeded in locating the fish at the remote Makemo Island atoll in French Polynesia, where 70% of the oyster shells boasted pearlfish lodgers. And Kéver recalls that the diving conditions on the atoll were idyllic. 'There is only one small scuba club, which means that we were always alone, except for a few locals', Kéver says with a smile. However, there were some drawbacks to the remote location, 'There was limited infrastructure and electricity,' Kéver explains. And he adds that bringing the tiny fish to the surface was also risky because of the pressure difference: it took almost an hour to bring the oysters and their fishy lodgers to the surface at the end of each dive session. Back on land, Kéver, Parmentier, Lerouvreur, Orphal Colleye and David Lecchini transferred the oysters with their fish into tanks to record the fish's sounds from outside of their oyster homes after dark. Analysing the structure of the calls, the team found that the each sound could last as long as 3 s and comprised trains of up to 40 broadband pulses that were dominated by three frequencies (212 Hz, 520 Hz and 787 Hz). Also, when Marco Lugli tested the shells' acoustics, they found two frequency bands (250 Hz and 500 Hz) that were amplified within the shells – possibly for communication with other pearlfish residents – while frequencies around 1000 Hz were amplified inside and out of the shells. 'Amplification probably improves the efficiency of communication by increasing the propagation distance of the sounds', says Kéver.

Having identified the main features of the fish's distinctive calls, the team brought some of the animals back to Europe to learn more about their unique sound-production system. After Kéver dissected the fish to begin learning about their anatomy, Anthony Herrel used high-resolution CT scans to reveal their unique sound-production system. Kéver describes the structures, saying, 'The rostral [front] end of the swimbladder forms a mineralised structure – called the rocker bone – on which insert the primary sonic muscles', adding that four of the vertebrae near to the swim bladder are also modified. Speculating that the rocker bone provides a solid anchor for the sonic muscles that vibrate the swimbladder, Kéver says, 'it is quite exceptional to see that soft tissue can be hardened when subject to certain constraints'. He also points out that there are differences between the male's and female's rocker bones. '[They] should allow the emission of two different signals and thus the recognition of the sex of the emitter' says Kéver, but points out that this is yet to be confirmed.

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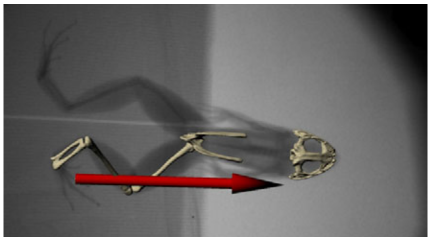
Kéver, L., Colleye, O., Lugli, M., Lecchini, D., Lerouvreur, F., Herrel A. and Parmentier, E. (2014). Sound production in *Onuxodon fowleri* (Carapidae) and its amplification by the host shell. *J. Exp. Biol.* **217**, 4283-4294.

Kathryn Knight

Soft catch prepares power for frog leaps



X-ray of a frog during a jump. Photo credit: Henry Astley and Keck Foundation XROMM Facility at Brown University.

When it comes to a list of the top animal jumpers, frogs are right up there, along with other members of the superleague, such as grasshoppers and fleas. Yet, how frogs pull off their remarkable ballistic feat was unclear. Henry Astley from Brown University, USA, explains that insects wind up for a jump by locking their legs in place while their muscles pull on an elastic piece of exoskeleton that stores energy ready for release when the catch is unleashed to power the leg's thrust. However, Astley and Tom Roberts were puzzled how frogs could produce the same explosive feat in a soft body. 'Jumping vertebrates lack a clear anatomical catch, yet face the same requirement to load the elastic structure prior to movement,' says Astley. Intrigued, the duo began filming the leaping amphibians with X-rays to find out more about how frogs power jumps (p. 4372).

Inserting minute metal markers that show up well in X-ray movies into the hind legs of three frogs (*Rana pipiens*) and filming the animals as they let fly, Astley and Roberts also recorded the forces exerted on the ground by the frogs' feet. Then the duo reconstructed the way that the frogs unfurled their legs in the last 150 ms before push off and calculating the amount of power produced by the amphibian's ankle extensor (plantaris) muscle. Amazingly, this muscle, which powers leaps, was capable of producing over four times as much power (1352 W kg^{-1}) as a normally contracting muscle (322 W kg^{-1}), confirming that the animals were storing elastic energy and using it to power take-off like some other frogs.

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Next, Astley and Roberts analysed the leg movement reconstructions, and realised that the frogs were storing elastic energy at the ankle by changing their posture to alter the leverage and forces acting around the joint. Describing this ‘dynamic catch’ mechanism, Astley explains that elastic energy can be stored in the plantaris muscle during the preparation phase of the jump when the leverage acting at the ankle is poor and the forces acting on the bent legs – such as the ground reaction force – resist movements at the ankle. However, in the later stages of preparation, the forces that had resisted the ankle’s movement fall to a point where the ground reaction force and leverage becomes great enough to release the energy stored in the plantaris muscle, launching the frog into the air.

Explaining that the leg forces and poor leverage that resist ankle movements in the early stage of a jump are analogous to the mechanical catch that allows jumping insects to store elastic energy, the duo suspects that other animals may also be able to take advantage of this dynamic catch mechanism to produce impressive leaps. However, they point out that there are situations where this mechanism will not work – such as leg kicking, when there are no ground reaction forces to hold the limb steady during preparation.

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Astley, H. C. and Roberts, T. J. (2014). The mechanics of elastic loading and recoil in anuran jumping. *J. Exp. Biol.* **217**, 4372-4378.

Kathryn Knight

Larvae sense bow wave for swift exit

If you can’t get out of the way fast when you’re tiny, there’s little hope for your future and even less for your offspring. However, nimble larvae appear to be able to sense approaching doom and take evasive action even before the attacker is within range. ‘It is unclear how the sensory systems of prey fish operate quickly enough to coordinate an evasive manoeuvre,’ says Matt McHenry and colleagues from the University of California, Irvine, USA, and the Woods Hole Oceanographic Institution, USA. However, there was a clue that the fish might be using a sensory system – the lateral line – that detects the motion of fluid flowing over the surface of their body to trigger their lightning-fast reaction. According to the team it takes a fish 200 ms to respond to a visual threat, whereas it takes them only 4 ms to respond to alterations in fluid flows. Intrigued by the possibility that the tiny victims might be able to sense water that is propelled in front of a predator, McHenry and his colleagues, William Stewart, Arjun Nair and Houshuo Jiang began investigating the reactions of minute zebrafish larvae to an approaching adult (p. 4328).

Zebrafish (*Danio rerio*) larva attempting to evade an adult. Photo credit: William Stewart.

Stewart designed a motor-driven sled that could be immersed in water to carry the body of a dead adult fish at speeds ranging from 2–20 cm s^{-1} and then filmed the responses of larval fish in the dark, forcing them to rely on their flow sensors alone as they fled from the approaching predator. Analysing the fish’s escape manoeuvres, the team realise that the larvae reacted when the predator was within 2 cm. They also noticed that the larvae that were off to the side of the predator’s line of attack performed the most effective escapes, consistently turning away from the approaching adult. And, when the team inactivated the sensors in the larvae’s lateral lines the larvae failed to respond to the adult’s approach; they would have been snapped up by a hungry predator.

Having shown that the lateral line is the sensory system that allows the larvae to take evasive action, the team turned their attention to the way that fluid is propelled by an approaching predator to find out what aspects of the fluid motion triggers the fish’s reaction. Building a computer simulation of the fluid motions generated by approaching predators, Jiang could see a pulse of fast-moving water – which they describe as a bow wave – preceding the model fish. And when the team visualised how the water around an approaching fish moved in real life, the bow wave was clearly visible.

Combining the detailed information about the bow wave structure from the simulation with their measurements of the larvae’s escape manoeuvres, the team realised that the fish’s swift reactions were triggered by the lateral line’s direct connection to the nerves that trigger the escape response on the opposite side of the larva’s body. ‘This circuit accounts for the ability of flow on one side of the body to stimulate motion on the opposite side’, says McHenry, adding that understanding the neuroscience and mechanics of the larvae’s evasive manoeuvres will help us build a better understanding of the relationship between predators and their prey.

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Stewart, W. J., Nair, A., Jiang, H. and McHenry, M. J. (2014). Prey fish escape by sensing the bow wave of a predator. *J. Exp. Biol.* **217**, 4328-4336.

Kathryn Knight
Kathryn@biologists.com