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Inside JEB

HOW STINGRAYS SENSE THEIR SURROUNDINGS


Laura Jordan

In some ways, stingrays are the Cinderellas of the elasmobranch world. Compared with their better-studied cousins, the sharks, little is known about the ways that stingrays sense their environment. Coupled with that, stingrays seem to have a major disadvantage relative to the majority of other fish; their eyes are on the opposite sides of their bodies from their mouths. This probably makes snatching a snack tricky so stingrays must rely on senses other than vision when searching for food. Curious to find out how stingrays sense their surroundings, a pair of scientists from UCLA, Laura Jordan and Malcolm Gordon, and Stephen Kajiura from Florida Atlantic University, decided to investigate how three stingray species sense and react to signals that their prey may send (p. 3037, p. 3044).

First, Jordan had to find some stingrays. Heading to Santa Catalina Island off the California coast, Jordan went fishing, collecting round stingrays with a seine net and pelagic stingrays on a long line. But to collect bat rays she and a buddy donned SCUBA gear and went fishing beneath the waves with a supersized hand net. Jordan explains that she had to be stealthy and quick to capture bat rays resting on the seabed. ‘Once a fish had swum off, I had little or no chance of catching it,’ remembers Jordan.

Returning to the Wrigley Marine Science Center with the stingrays, Jordan began testing the fish’s responses to jets of water (p. 3037). Jordan explains that bat rays spend most of their time on the seabed searching for buried clams and bivalves, so she decided to simulate the telltale jets of water produced by the bat ray’s favourite molluscs to see how all three species react to fluid movements.

Releasing individual hungry rays into a pool, Jordan filmed all three species’ reactions. Not surprisingly, the bat rays reacted most enthusiastically as they swam over the jets, stopping and biting at the jet as if it were produced by a tasty mollusc. The least responsive of the three fish was the pelagic ray, which is the only stingray that hunts in open water and dines on squid and fish. Despite coming across the jets more often than the other two species, the pelagic ray only reacted to 32% of the jets, where as the round and bat rays reacted to 40% and 60% of the jets they encountered.

Knowing that all fish detect fluid movements with an organ known as the ‘lateral line’ (a series of pores at the skin surface that are linked by fluid-filled channels just beneath the skin), the team related the distribution of lateral line pores at the skin surface to the animals’ reactions to their encounters with the jets. The jet-sensitive bat ray had the highest density of lateral line pores along its skin, where as the less responsive pelagic and round rays had low pore densities. However, the underlying canals that link the pores are more branched in the round ray than the pelagic ray, which was the least responsive of them all. And even though the flow sensitive pores were only distributed across 70% of the disc of the round and pelagic rays’ bodies, the rays were still able to respond to jets that touched the tips of their fins despite lacking pores at the outer perimeter of their bodies. ‘This was a big surprise for me,’ says Jordan.

Having tested the fish’s reactions to jets of water, Jordan and her colleagues turned their attention to the fish’s sensitivity to electric fields (p. 3044). Knowing that all elasmobranches can detect electric fields and that the distributions of electrosensitive pores across the skin surfaces of all three rays differed significantly, the team decided to test the fish’s reactions to weak electric dipole fields, similar to the fields generated by the small crustaceans beloved by round and bat rays.

This time Jordan and Kajiura designed a plate with four dipole electrodes attached to it that could be placed in the bottom of the rays’ pool. Back at the Wrigley Marine Science Center, Jordan switched on each dipole randomly, varied the electric fields from 5.3 to 9.6 $\mu V\,cm^{-1}$ and filmed the rays as they homed in on, and bit at, the tempting electric field. Analysing the fish’s reaction to the fields, it was clear that all of the fish were extremely sensitive to the electric fields and were able to detect fields as weak as 1 $nV\,cm^{-1}$. However, the bottom-dwelling bat and round rays, both with higher densities of electrosensory pores around their mouths, attacked the dipole more enthusiastically than the pelagic ray, which has lower densities of electrosensitive pores. The round and bat rays were also able to pinpoint the dipole’s location more accurately than the pelagic ray, stopping precisely over the dipole at the end of their single approach run, while the larger pelagic ray often overshot the dipole before reversing into place.

Jordan suspects that the differences in the stingrays' performances are related to their different lifestyles. As round rays are confirmed seabed residents, and bat rays spend much of their time foraging for buried critters, both species probably rely heavily on their sensitivity to electric fields and jet-like fluid flows when searching for a meal. However, pelagic rays probably rely more on their vision when homing in on a tasty fish, and switch to their other senses once lunch is within reach.

10.1242/jeb.037366

Jordan, L. K., Kajiura, S. M. and Gordon, M. S. (2009). Functional consequences of structural differences in stingray sensory systems. Part I: mechanosensory lateral line canals. *J. Exp. Biol.* **212**, 3037-3043.
Jordan, L. K., Kajiura, S. M. and Gordon, M. S. (2009). Functional consequences of structural differences in stingray sensory systems. Part II: electrosensory system. *J. Exp. Biol.* **212**, 3044-3050.

MIGRATING BLACKCAPS CHILL TO FATTEN UP


Ortal Mizrahy

Marathon runners are famed for pasta packing in the days before a big run but when tiny passerine birds set out on their epic migrations, the distances are too great to cover on the reserves with which they embark. Michał Wojciechowski and Berry Pinshow explain that most birds stop off en route to their destination to refuel. One of the Eurasian blackcaps' preferred refuelling stops is Midreshet Ben-Gurion, Israel, where the birds fill up on fruit and insects before setting off again. Knowing that birds expend twice as much energy during stopovers than they use in transit, the duo wondered whether the tiny aviators may drop their body temperature at night during stopovers to save energy and build up their reserves faster (p. 3068).

Collecting migrating blackcaps at their stopover site on the Sede Boqer Campus of Ben-Gurion University, Wojciechowski and Pinshow weighed the birds and monitored their body temperatures and metabolic rates as the birds stocked up on fruit supplemented with mealworms. During the day the birds' body temperatures hovered around 42.5°C, but as dusk fell, their temperatures began to drop. The average normal body temperature at night was about 38.8°C, while one particularly skinny individual's temperature plummeted to 33°C. And when the team plotted the birds' body masses against their nocturnal body temperatures, the smaller birds' (<16.3 g) temperatures correlated with their body masses but the larger birds' (>16.3 g) body temperatures did not.

Finally, the team looked at the relationship between the birds' temperatures and their metabolic rates and found that the heavier birds dropped their metabolic rates least, while the lightest birds dropped their metabolic rates most. Some conserved a remarkable 30% of their energy by becoming hypothermic.

Knowing that small birds also conserve energy by huddling together for warmth, Wojciechowski and Pinshow suggest that migrating birds may combine both strategies to shorten refuelling stopovers to fatten up fast before hastening on their way.

10.1242/jeb.037358

Wojciechowski, M. S. and Pinshow, B. (2009). Heterothermy in small, migrating passerine birds during stopover: use of hypothermia at rest accelerates fuel accumulation. *J. Exp. Biol.* **212**, 3068-3075.

HAIR HIERARCHY HELPS *R. GORGONIAS* GET A GRIP

Unfortunate insects that come into contact with a *Roridula gorgonias* leaf don't stand a chance. Within moments the struggling victim is swathed in sticky secretions exuding from the leaf's hairs, and its fate is sealed. Curious to find out exactly how *R. gorgonias* leaves ensnare their prey, Dagmar Voigt and Elena and Stanislav Gorb from the Max Planck Institute for Metals Research and Kiel University, Germany, decided to take a closer look at the hierarchy of hairs on *R. gorgonias* leaves (p. 3184).

Measuring the length of the leaves' hairs, the team could see that they fell into three classes: long slender hairs ranging from 3.3 to 5 mm, medium length thicker hairs from 1 to 2.4 mm and short fat hairs from 0.3–0.7 mm. And when they tested the hairs' stiffness, the long thin hairs were the most flexible, while the medium length hairs were almost 4 times stiffer and the short hairs were almost 50 times stiffer, bending only at the bottom of the shaft.


Dagmar Voigt

Next the team sandwiched the adhesive secretions, from all three hair types, between glass coverslips and tried to pull them apart to measure the adhesive's stickiness. The longest hairs produced the weakest of the three adhesives (17.5 kPa), while the medium length hairs were almost 1.5 times stickier (24.5 kPa) and the short hairs' adhesive registered 156.2 kPa; almost 4 times the strength of flypaper glue.

So how do these sticky hairs entrap a victim? Voigt and her colleagues suspect that hapless insects fall foul of the plant's sticky leaves in a cascade of events. First, the insect brushes against, and sticks to, a long hair. As it begins to thrash around, it contacts more of the long hairs, becoming entangled in their sticky secretions. Next, it contacts the stiffer medium length hairs with intermediate strength adhesive and is finally trapped by the rigid short hairs with the strongest glue. Eventually the struggling insect runs out of energy and is immobilised.

Given the effectiveness of *R. gorgonias*' natural flypaper, Voigt and her colleagues are excited to have discovered the hair hierarchy mechanism that helps *R. gorgonias* get a grip.

10.1242/jeb.037341

Voigt, D., Gorb, E. and Gorb, S. (2009). Hierarchical organisation of the trap in the protocarnivorous plant *Roridula gorgonias* (Roridulaceae). *J. Exp. Biol.* **212**, 3184-3191.

CORRECTION: HOW NORTHERN TARDIGRADES WEATHER WINTER

In the article entitled 'How northern tardigrades weather winter' (doi: 10.1242/jeb.036152) published online on 14 August 2009, the accompanying image was incorrectly attributed to Nadja Møbjerg. The image should have been attributed to Kenneth Halberg and Dennis Persson. We apologise for this error.

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