

INSIDE JEB

Super-sensitive seal whiskers feel fish breath



Henry the seal preparing to test the sensitivity of his whiskers to jets of water. Photo credit: Marine Science Center Rostock.

Plunging through gentle swell in the northern oceans in search of food, harbour seals are guided by a cryptic superpower that few fish can evade. 'Fish produce lots of water flow that remains in the water, even after the fish has gone', says Wolf Hanke, from the University of Rostock, Germany, and it is these swirling wakes that betray the presence of fish dinners. A hungry seal can sense the tell-tale turbulence left by a passing fish with flow-sensitive whiskers on its snout, before pursuing the hapless victim's trail. However, seals are not limited to hunting in open water. Explaining that it was apparent from crittercam movies that the diving mammals also stalk seafloor-dwelling species, Hanke and his colleagues were curious to find out how seals pinpoint well-camouflaged static flatfish that would evade even the sharpest eyes. Could the predators be honing in on the gentle jet of water produced by the concealed fish's gills with their super-sensitive whiskers?

Having studied the seals' extraordinarily sensitive flow sensation for more than a decade, Guido Dehnhardt's team at the University of Rostock had three willing harbour seal colleagues – Henry, Filou and Luca – who were well prepared to help tackle this question. And despite living in captivity all of their lives, the animals were adept at catching flatfish on the bottom of their outdoor enclosure: 'The fish enter the netting of the semi-natural enclosure and the seals hunt them', says Hanke. However, working in the semi-natural setting has its drawbacks,

as it was difficult to measure the speed of the jets of water encountered by the seals against the background of the sea's natural turbulence.

As camouflaged flatfish angle pulses of water upward at about 45 deg out of their gills, Hanke and Benedikt Niesterok constructed a platform 1 m below the surface of the enclosure with eight angled nozzles that could be independently activated by a pump to simulate a flounder exhaling at $\sim 25 \text{ cm s}^{-1}$. Then, having trained the seals to swim counter-clockwise around the platform with and without a blindfold, Niesterok, Hanke, Yvonne Krüger and Sven Wieskotten filmed the animals' responses and were impressed to see that the blindfolded seals could sense a continuous jet of water, regardless of the direction from which they approached. And when the team stepped up the challenge by pulsing the simulated breath jet to reproduce the exhalation pattern of a flounder, both of the animals that participated in the test successfully picked out the active nozzle with their whiskers. However, high-speed approaches impacted on their success, with the animals overshooting the fake flounder at speeds of 1.3 m s^{-1} , while they recorded the most success at speeds ranging from 0.4 to 0.8 m s^{-1} . Niesterok also noticed that one of the seals retracted its head towards its shoulders as it closed in on the jet of water; 'It can move its head in a way that slows down the sensory system in the water, using the head movement and not the swimming itself', Hanke says.

Having confirmed that the seals' sensitive whiskers are capable of detecting the breathing currents of flatfish submerged beneath the sand and knowing that many fish species are capable of holding their breath, Hanke speculates that flatfish may stop breathing deliberately to avoid revealing their location as seals sail past. 'It seems conceivable that the detection of breathing currents by predators is one of the evolutionary drivers for this respiratory suppression in fish, he says'.

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Niesterok, B., Krüger, Y., Wieskotten, S., Dehnhardt, G. and Hanke, W. (2017). Hydrodynamic detection and localization of artificial flatfish breathing currents by harbour seals (*Phoca vitulina*). *J. Exp. Biol.* **220**, 174-185.

Kathryn Knight

Charred remains trigger torpor in antechinus survivors



A yellow footed antechinus, *Antechinus flavipes*. Photo credit: Clare Stawski.

Few creatures can outrun a forest fire as it engulfs everything in its path. For small marsupials, such as fat-tailed dunnarts and yellow-footed antechinus, the best hope is to nestle deep down in burrows and in nests in rocky fissures until the inferno has passed over. However, the aftermath can be equally as risky as the flames themselves. 'We were interested in how animals can survive after a fire, when the landscape is often devoid of food and vegetative ground cover', says Clare Stawski, from the University of New England, Australia. Having already discovered that one successful survival strategy is to hunker down and go into torpor – when the animal lowers its body temperature and reduces its metabolic rate to conserve energy – Stawski and her colleagues Fritz Geiser, Julia Nowack and Gerhard Körtner were curious to find out which factors trigger the onset of torpor in animals that have survived a blaze.

Reasoning that the food scarcity is a cue that could trigger an energy-conserving drop in body temperature, Stawski and her colleagues also wondered whether smoke and the environmental scars that remain – such as ash and charcoal – could also trigger torpor in antechinus wildfire

survivors. ‘It took several weeks to capture enough animals in the wild’, says Stawski, who explains that the nocturnal animals are most active on warm nights; ‘our capture rates were often sporadic and influenced by the weather’, she recalls. Back in the lab, Stawski and Körtner gently inserted minute temperature loggers inside the animals’ body cavities before allowing them to roam free in an enclosure. Then, Stawski and Nowack embarked on a month-long series of experiments in which the antechinus experienced a series of situations that they might undergo during and after a fire, including: smoke billowing through the enclosure, reduced food supply and, on one occasion, ash and charcoal spread over the ground to simulate the conditions after a firestorm. Meanwhile, the team recorded the marsupials’ body temperatures in search of the tell-tale temperature dip that is the hallmark of torpor.

Remarkably, each of the scenarios triggered a significant drop in the animals’ body temperatures. While the females doubled the amount of time that they dropped their body temperatures to conserve energy in response to each of the wildfire scenarios, the males increased the amount of time when they were torpid 6.5-fold when smoke filled the enclosure and their food supply was reduced by half. However, when Stawski and Nowack spread ash and charcoal throughout the enclosure, the small marsupials increased the amount of time they were torpid by 14.3-fold. ‘We were surprised that the combination of charcoal and ash with smoke and food reduction elicited such a strong response’, says Stawski. In addition, she noticed that the usually nocturnal animals became significantly more active during daylight at the first sniff of smoke. She says, ‘It is likely that smoke is perceived as a warning signal’, which probably gives the animals a chance to find a refuge and improve their chances of survival.

Having discovered that antechinus use a combination of cues – including charred remains, ash, smoke and food reduction – to trigger torpor and hunker down in the wake of an inferno, Stawski is now keen to learn more about how antechinus populations recover after fire has swept through.

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Stawski, C., Nowack, J., Körtner, G. and Geiser, F. (2017). A new cue for torpor induction: charcoal, ash and smoke. *J. Exp. Biol.* **220**, 220–226.

Kathryn Knight

Lateral line makes Pachón cavefish sleepless



A Pachón cavefish at the surface of the water. Photo credit: Pavel Masek.

As life choices go, it might seem extreme, but for blind Mexican cavefish, the choice to forgo sight was probably a no-brainer: eye running-costs are high in the dark, oxygen-poor cave waters where the fish make their homes. In addition, many truly sightless cavefish also make do with very little sleep, requiring as little as 5–20% of the sleep required by their surface-dwelling cousins. But Alex Keene, from Florida Atlantic University, USA, highlights that ‘little was known about the neural mechanisms underlying this dramatic behavioural shift’. Intrigued by the phenomenon, Keene and graduate student James Jaggard began investigating the neural mechanisms that have led cavefish populations to reduce their dependence on sleep.

Explaining that sleep is defined as occurring when animals are slow to respond to physical stimuli, Jaggard focused on the Pachón cavefish population – which have dramatically reduced their eyes – filming the fish for 24 h to determine how long they sleep. Categorizing fish as asleep when they ceased moving for 60 s or more, Jaggard noticed that the cave fish took fewer sleep bouts, only achieving a total of ~1 h of sleep a day, compared with the ~7 h taken in more frequent bouts by the sighted relatives above ground. But what mechanism has caused the cavefish to cut their sleep so dramatically?

As sensory systems – such as vision, hearing and smell – are known to play a significant role in regulating sleep, Jaggard and Keene decided to inactivate the fish’s lateral line – which senses water flow and the presence of prey – to find out whether that system affected the fish’s sleep pattern. Bathing the fish in the antibiotic gentamicin, which damages vibration-

sensitive hair cells in the hearing systems of mammals, Keene recorded the fish’s sleep patterns and was impressed to see that the cavefish now slept as much as their surface cousins. This suggests that enhanced sensory input underlies the evolutionarily derived sleep loss in Pachón cavefish, and the team adds, ‘these findings reveal a wake-promoting role for the lateral line’. However, when Jaggard tested the impact of gentamicin on other sleepless cavefish populations (Molino, Tinaja, Los Sabinos and Chica cavefish), none of them gained more sleep time, suggesting that each of the subterranean populations has independently evolved distinct mechanisms for regulating sleep.

Another question that intrigued Jaggard and Keene was why cavefish miss out on sleep. As sleep loss could extend the time available for foraging in their barren cave homes, the duo starved Pachón fish and discovered that the hungry animals increased the amount of sleep to ~6 h day⁻¹. So, the fish may be able to modulate the amount of sleep that they take depending on food availability to maximise foraging opportunities when food is available.

Finally, Jaggard tested which flow sensitive receptors on the surface of the Pachón fish are responsible for keeping the fish awake longer, by selectively coating the flow sensors on different portions of the body with adhesive. Recording how much the fish slept, Jaggard could see that the flow sensors on the fish’s head and trunk were essential for regulating sleep, as the treated fish slept more. And when he compared the amount of time that the fish indulged in sleep between individuals – which can vary significantly – it was clear that the fish that slept the least had the greatest numbers of flow sensors.

Summing up, Keene says, ‘The evolution of enhanced sensory capabilities contributes to sleep loss in cavefish’, and he is eager to selectively disable the lateral line sensors in order to learn more about their contribution to sleep regulation in these extraordinary fish.

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Jaggard, J., Robinson, B. G., Stahl, B. A., Oh, I., Masek, P., Yoshizawa, M. and Keene, A. C. (2017). The lateral line confers evolutionarily derived sleep loss in the Mexican cavefish. *J. Exp. Biol.* **220**, 284–293.

Kathryn Knight

Wolf spiders' three pairs of odometer eyes



Lurking at the top of a burrow concealed in a cunningly constructed turret of twigs, leaves and stones, hungry wolf spiders (*Lycosa tarantula*) keep all eight eyes peeled, ready to ambush the next passing meal. However, after pursuing and subduing the hapless victim, the ravenous arachnid has to drag its quarry home before feasting. Joaquín Ortega-Escobar, from the University Autónoma of Madrid, Spain, explains that the spiders keep track of the direction and distance travelled on the outbound leg of the hunt, so that they can return home along the most direct route instead of retracing their steps directly. The animals rely on a polarized light compass associated with the minute pair of anterior median eyes at the front of the head to determine their orientation, and an odometer that measures the movement of images across the retina to determine the distance covered. However, it was not clear which of the four pairs of eyes

the wily arachnids use to keep track of how far they have travelled.

After training the spiders to run 30 cm along a channel lined with stripy wallpaper to their burrow, Ortega-Escobar fitted water-soluble blinds to the spider's posterior lateral eyes and posterior median eyes, and then encouraged the spiders to scamper home. Impressively, the spiders were able to accurately gauge the return distance when the large posterior median eyes were covered; however, when the posterior lateral eyes were obscured, the spiders pulled up 3 cm short of their home site. And the spiders' ability to estimate the distance travelled was most compromised when the stripy wallpaper was replaced with a stripy carpet. Coating the tiny anterior lateral eyes and the posterior median eyes in black paint, the spiders stopped 7 cm short of the full 30 cm home run when the anterior lateral eyes were

covered, but only stopped 3 cm before the burrow when the large posterior median eyes were covered.

So the two outermost pairs of eyes and the posterior median eyes in the front of the spider's head hold the key to the arachnid's ability to keep track of how far it has travelled, and Ortega-Escobar says, '*L. tarantula* probably integrates the information gathered through the anterior lateral eyes and the posterior median eyes to get an image of the changes observed in the substratum that can be used for orientation when returning to their burrow after looking for prey'.

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Ortega-Escobar, J. and Ruiz, M. A. (2017). Role of the different eyes in the visual odometry in the wolf spider *Lycosa tarantula* (Araneae, Lycosidae). *J. Exp. Biol.* **220**, 259-265.

Kathryn Knight
kathryn.knight@biologists.com