INSIDE JEB

UFO cross-section gives snakes a lift

The paradise tree snake, *Chrysopelea paradise*. Photo credit: Jake Socha.

If you're afraid of snakes, you're really not going to like the next bit: some snakes can fly. It sounds like a frightful nightmare, but for Jake Socha, the discovery was the start of a fascinating odyssey to learn how an animal that looks as unaerodynamic as a snake can glide as much as 30 m from a tall tree. Socha describes the snakes as 'slithering' in an S-shape through the air as they descend through the Southeast Asian rainforest: 'They look like they are swimming', he adds. But what keeps the reptiles aloft? 'They turn their whole body into one aerodynamic surface', explains Socha – who has spent much of his career unpicking details of the snake's flying style – and has now turned his attention to the animal's intriguing body shape to find out how they generate the lift they require to remain airborne (p. 382).

According to Socha, the snakes flex their ribs as they launch to stretch and flatten the body to change their profile from a circle into an arched semi-circle: 'It looks like someone's version of a UFO', laughs Socha, adding that as aerofoils go it's an unconventional shape. To get to grips with the aerodynamic forces generated by the snake's body, Socha and his colleagues, Daniel Holden, Nicholas Cardwell and Pavlos Vlachos, used a 3D printer to produce a rod with the same UFO cross-section as the snake's body before placing it across a tank filled with water that flowed over the snake-shaped bar. Socha explains that although water is much denser and stickier than air, you can precisely recreate the air conditions experienced as the snakes fly by flowing the water over the model at a specific range of speeds.

Tilting the snake model at angles (of attack) ranging from –10 to 60 deg as the water flowed over it at speeds ranging from 20 to 50 cm s^{-1}, the team measured the lift and drag forces pulling on the model and saw that at most angles the animal's unusual body shape generated sufficient lift to account for some of the snake's impressive gliding performance. But when the team tilted the model at 35 deg, there was a massive spike in the lift generated by water flowing at higher speeds. More surprisingly, when the model was held level with the flow, instead of generating upward lift, the fluid pushed the rod down. And when the team visualised the turbulent water flowing around the model with microscopic reflective beads, they could clearly see a spinning vortex sitting beneath the untilted snake shape, sucking it down: which may not be that crazy, according to Socha. He says, 'Maybe the snake does hold part of its body flat at some point, using it as a mechanism for control', explaining that twisting the body while airborne could allow the snakes to fine tune the forces on their bodies for precise flight control.

But Socha adds that there is much more to the snake's impressive glide than just its unusual body shape. 'If you make a rough estimate of the lift to drag ratio for the real animal, it appears to do better than what we got from this study. So even though this shape produced more lift than we were expecting, it doesn't get us the glide performance that snakes can attain, giving us a hint that there is something in what the animal is doing aerodynamically that is not captured by the cross-sectional shape alone' – which is the next part of the problem that Socha and his team hope to crack.

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Holden, D., Socha, J. J., Cardwell, N. and Vlachos, P. P. (2014). Aerodynamics of the flying snake *Chrysopelea paradisi*: how a bluff body cross-sectional shape contributes to gliding performance. *J. Exp. Biol.* **217**, 382-394.

Kathryn Knight

Ocean acidification will interfere with fish eyes

Spiny damselfish, *Acanthochromis polyacanthus*. Photo credit: Joao Krajewski.

The idyllic coral sands and crystal seas that lap the Great Barrier Reef are probably most people's definition of a tropical paradise: but all is not well in paradise. As global CO_2 levels rise, the pH at the surface of the oceans is gradually falling. Göran Nilsson from the University of Oslo, Norway, explains that dissolved CO_2 levels are predicted to rocket by the end of the century, increasing by approximately 500 μatm from today's level of about 400 μatm. The resulting 0.4 drop in the water's pH will dramatically affect the reef's inhabitants by altering their ion balance and disrupting one of the brain's key neurotransmitters: GABA. 'GABA performs a function in virtually all neural circuits in the brain', says Nilsson, who explains that alterations to the system can dramatically disrupt behaviour, making predators attractive and increasing the boldness of usually shy creatures. Nilsson adds that juvenile damselfish also fail to respond correctly to glimpses of a predator after exposure to elevated CO_2 and says, 'This suggests that the function of the visual system is affected by high CO_2'. Curious to find out how increasing ocean acidification might affect the vision of residents of the Barrier Reef, Nilsson, Wen-Sung Chung, Justin Marshall, Sue-Ann Watson and Philip Munday decided to find out how increased CO_2 alters the visual responses of damselfish retinas by focusing on the speed of the retina's response to flickering light (p. 323).

The team explains that we can see lights flickering until the flicker reaches a specific frequency – the critical flicker

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fusion (CFF) – at which point the retina no longer responds fast enough and the image appears to stop flickering. The retina's response is often correlated with an animal's lifestyle. Creatures that live in brightly lit environments that are also good at evading predators usually have higher CFFs than sluggish animals that live in dim conditions.

The team recorded the electrical activity of the damselfish's eye as they shone a flickering light into it, increasing the flicker rate until the pattern of the eye's electrical activity no longer matched the light's flicker; this was when they reached the fish's CFF and the animal could no longer distinguish the flicker. The fish kept at today's CO_2 level had a high CFF of around 90 Hz, while it had fallen to about 78 Hz in fish that had experienced 6 days at the CO_2 levels that are predicted by the turn of the next century (944 μatm). 'Having good temporal resolution is critical to detect fast-moving objects', says Chung, and Nilsson adds, 'It is likely that the reduction will translate into a reduced ability to react to fast events, probably by 10–15%.'

Next, the team tested whether the increased CO_2 exposure had affected the fish's GABA signalling system. They activated the $GABA_A$ receptor – which is usually activated by GABA – with an agonist to see whether they could restore the CO_2-exposed fish's impaired flicker response, and the treatment worked, successfully restoring the fish's performance.

It seems that increasing CO_2 levels will impact the vision of reef residents, but it is hard to predict how this will affect the reef's ecology. Nilsson says, 'We expect that the sensitivity of the CFF to high CO_2 will vary between species... If a particular prey is more sensitive than some of its predators, it could have negative consequences for the prey... but one can speculate that the opposite situation may also occur (that the predators become slower in their visual responses), which would be beneficial for the prey.'

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Chung, W.-S., Marshall, N. J., Watson, S.-A., Munday, P. L. and Nilsson, G. E. (2014). Ocean acidification slows retinal function in a damselfish through interference with $GABA_A$ receptors. *J. Exp. Biol.* **217**, 323-326.

Kathryn Knight

Diving beetle larvae eschew conventional range finding

Larvae of the sunburst diving beetle, *Thermonectus marmoratus*. Photo credit: Elke Buschebeck.

The larvae of sunburst diving beetles have voracious appetites: 'In their larval stages, all they do is eat,' laughs Elke Buschbeck, a neurobiologist from the University of Cincinnati, USA. Devouring around 800 mosquito larvae during development, the beetle larvae are equipped with six pairs of eyes to pursue their prey. 'I was looking for a holometabolic [metamorphosing] insect larva that was good at vision and was a predator', recalls Buschbeck, so when the curator of the Cincinnati Zoo and Botanical Gardens Insectarium told her about the insatiable creatures, she took a peek inside their eyes and made a remarkable discovery. The eye had two retinas, one above the other, and when Buschbeck focused the image of an object through the lens she saw that the lens was bifocal: it could focus two images, possibly with one on each retina. But why would the larvae develop such an unconventional eye? Puzzled, Buschbeck decided to find out whether the larvae could use the bifocal system to gauge distances, specifically the distance to their next meal. But testing this directly is tricky, so Buschbeck and her colleagues decided first to rule out other mechanisms that the larvae might use to decide when they are within striking distance of a tasty morsel (p. 327).

According to Buschbeck, the larvae could use various strategies for gauging distances and she decided to test the three most likely alternatives: stereo vision, where the larvae could interpret subtle differences between images of the object viewed through both eyes in a pair; motion parallax, where the larvae estimate the distance to an object based on the object's motion relative to the background when the larvae move their heads; and size matching, where the larvae approach the target until the image on the retina reaches a certain absolute size.

Teaming up with Kevin Bland and Nicholas Revetta, Buschbeck built a model mosquito larva that she could control to test the beetle larvae's responses. Then the trio monitored the ravenous larvae's reactions to small and large versions of the fake mosquito larva. Regardless of the size of the lure larvae, the beetle larvae always unleashed their ballistic attacks from the same distance – about 4 mm. So the beetle larvae were not using absolute image size to judge distance.

Next, the team tested whether the beetle larvae were using motion parallax to estimate distance. Buschbeck explains that this approach only works if the victim is stationary, so the team attempted to disrupt the beetle larvae's judgement by moving the fake larvae. However, the beetle larvae were unfazed, launching attacks whenever the counterfeit larva came within the 4 mm range. So the beetle larvae were not resorting to motion parallax for depth perception.

Finally, the trio attempted to disable the larvae's stereovision. Applying nail-polish blinds to the three main eyes on one side of a larva's head, the team tested whether the larvae could still grab a bite – which they did. And when Annette Stowasser calculated whether it was possible that the larvae could use two pairs of eyes on one side of the head for stereovision, it was clear that the eyes were too close together for stereovision to work.

No matter what the team tried doing to disrupt the larvae's depth perception, the larvae were always able to judge when they were within striking range. They were not using any of the conventional approaches to estimate distance and now Buschbeck is keen to know just how they use their two-tier/bifocal lens eyes to estimate distance.

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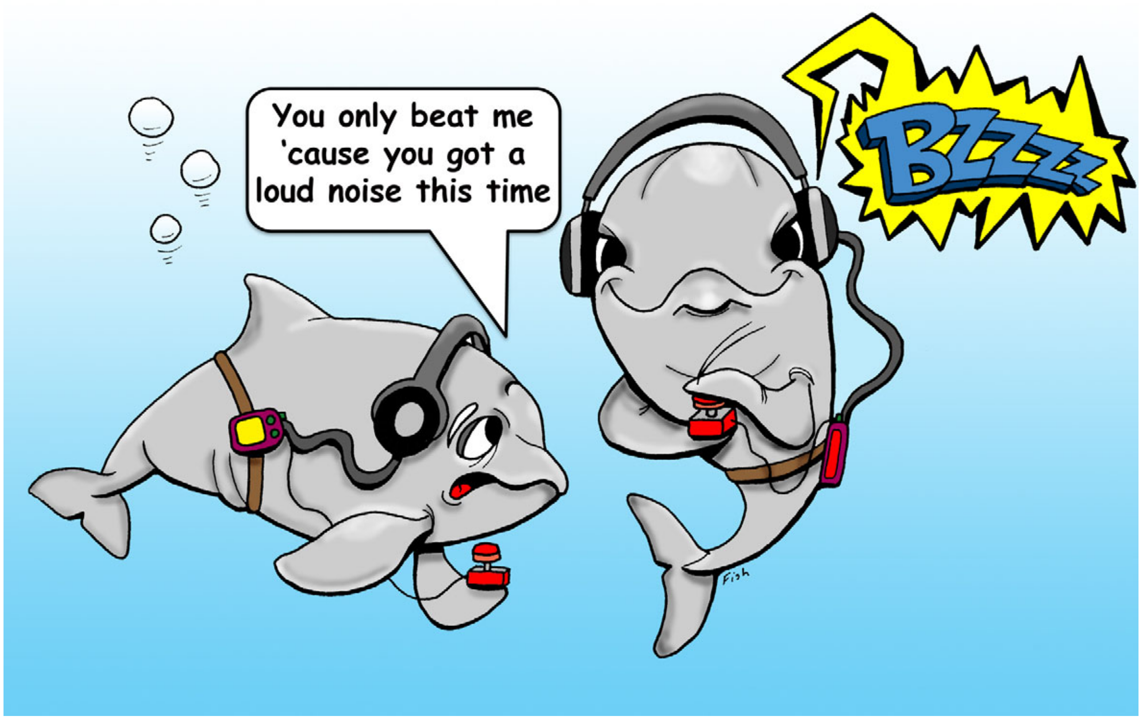
Bland, K., Revetta, N. P., Stowasser, A. and Buschbeck, E. K. (2014). Unilateral range finding in diving beetle larvae, *J. Exp. Biol.* **217**, 327-330.

Kathryn Knight

Porpoise reaction times recorded



Whales and dolphins have extremely acute hearing, which they use for navigation, communication and pursuing prey. But increasing human activity in the oceans is now raising alarm about the impact that our noisy lifestyle is having on these sensitive creatures. 'Concern… has led to attempts to establish acoustic safety criteria for underwater noise', says Paul Wensveen from the University of St Andrews, UK, working with colleagues from the Sea Mammal Research Company in The Netherlands. Unfortunately, measuring an animal's perception of sound volume can be particularly challenging: James Finneran and Carolyn Schlundt conducted thousands of perceived loudness trials with a bottlenose dolphin to measure its hearing in their 2011 *Journal of the Acoustic Society of America* paper. However, Wensveen and colleagues explain that an animal's loudness perception can be tested with a simpler method, used on human infants and animals, where the time that it takes a child or animal to respond to a sound is used as an indication of the sound's loudness: humans and animals respond faster to loud sounds than they do to soft sounds (p. 359).

Working with Jerry, a young adult male harbour porpoise who was trained to respond to very soft sounds by swimming away from a holding station, Wensveen and colleagues spent several months measuring his reaction times to sounds ranging in frequency from 0.5 to 125 kHz at sound pressure levels (volumes) from 59 to 168 dB re. 1 μPa. The team then calculated a series of auditory weighting functions, which can be used as indicators of how Jerry and other harbour porpoises of a similar age perceive the loudness of sounds. The team says, 'Behavioural and physiological responses of marine mammals to noise correlate better with the perceived loudness of a sound than with the unweighted sound pressure level', and they hope that Jerry's auditory functions could be used to set safer limits on human aquatic noise to better protect cetacean hearing.

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Wensveen, P. J., Huijser, L. A. E., Hoek, L. and Kastelein, R. A. (2014). Equal latency contours and auditory weighting functions for the harbour porpoise (*Phocoena phocoena*). *J. Exp. Biol.* **217**, 359-369.

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