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INSIDE JEB

Goshawk hunt and prey-evasion strategies revealed

Shinta wearing spy camera helmet in flight. Photo credit: Robert Musters.

Stealth is the goshawk's greatest asset. Plummeting out of the air, the raptors fix their gaze on the oblivious victim below. Intrigued by the birds' attack tactics, Suzanne Amador Kane from Haverford College, USA, decided to find out more about the factors that guide a goshawk during its approach and in the final instants before a strike. However Kane knew that she could only begin to understand the hunters' strategy from a bird's-eye perspective, and to do that she would have to team up with an experienced falconer (p. 212).

Taking advantage of academic contacts, Kane linked up with Robert Musters – a falconer from The Netherlands who works regularly with biomechanics to study bird flight – and his 2.5-year-old goshawk, Shinta. 'Robert is an inventor and engineer and he designed the helmet that Shinta wore,' says Kane, who supplied Musters with the tiny spy camera that was mounted on the bird's head. However, once Shinta was released into the wild Musters had no control over where she flew or what she filmed, 'She would film whatever she encountered', chuckles Kane.

After sifting through several hours of hunting footage, Kane found 16 short pursuits to investigate with undergraduate researchers Andrew Fulton and Lee Rosenthal. Manually analysing the motion of background objects in the bird's vision and the position of the target during her approach, Kane was able to extract information about Shinta's trajectory in the majority of attacks and the evasive action taken by the rabbit or pheasant that was in her sights.

Explaining that goshawks usually spy out their victims from a vantage point before launching an attack, Kane describes how Shinta first made a beeline towards her prey by holding the victim in the centre of motion of her gaze to minimise the time to impact and optimise the surprise factor. Then, once the target had been startled and was running for its life, the goshawk switched to a pursuit strategy where she held the prey at a constant angle in her vision as she closed in. Kane explains that this allows the predator to intercept its victim in the fastest time while also masking the attacker's approach from the victim's perspective. However, once she was within striking range Shinta switched strategy again, flying parallel to the fleeing animal, which gave her time to decide when to strike. And when Kane compared Shinta's tactics with those of goshawks filmed by British falconers David and Adam Burns from the ground, she often saw the same pattern of behaviour as she had seen previously when the goshawks closed in for the kill. However, Kane adds that although she would expect goshawks to use this strategy in the majority of cases, she says, 'you would expect them to use different strategies in certain circumstances'.

Having identified the key components of the goshawk attack, Kane says, 'One of the other things we wanted to study was how the prey try to evade capture'. Analysing the escape trajectories of the rabbits and pheasants that successfully eluded capture, Kane, Fulton and Rosenthal realised that the survivors made a sharp sideways turn away from the predator. 'In our videos you could see that only the sideways motion was effective at breaking the visual fix', says Kane. Adding that there is no way that a rabbit or pheasant could usually out run or out manoeuvre super agile goshawks, Kane suggests, 'Maybe what they are trying to do is counter the sensory abilities of the predator. They are trying to take advantage of the way the predator does its visual guidance to escape'.

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Kane, S. A., Fulton, A. H. and Rosenthal, L. (2015). When hawks attack: animal-borne video studies of goshawk pursuit and prey evasion strategies. *J. Exp. Biol.* **218**, 212-222.

Kathryn Knight

Squid flicker and flash for communication and camouflage

Humbolt squid wearing a Crittercam in the Sea of Cortez. Photo credit: Joel Hollander.

It is sometimes said that we know more about the dark side of the moon than we do about the residents of our deepest oceans, so when Hannah Rosen and her colleagues from Stanford University, USA, got the chance to hook up with Greg Marshall and his legendary Crittercam from National Geographic to study the giant Humboldt squid (*Dosidicus gigas*), the scientists leapt at the opportunity. Rosen explains that squid are covered in minute chromatophores that expand and contract to change colour, and adds that coastal species use their chromatophores to blend in with their surroundings. However, the open ocean is a relatively featureless environment, offering few opportunities for creative camouflage, leading Rosen, William Gilly and Lauren Bell to wonder how Humboldt squid use their colour-shifting abilities in the ocean's vast expanse (p. 265).

Heading out into the Gulf of California, Gilly and Kyler Abernathy went fishing for giant squid. 'Humboldt squid were very abundant in the Gulf when this study took place, so catching the squid using fishing rods and squid jigs was fairly simple,' recalls Rosen. Although catching squid of the right size was less easy as the animals had to be over 80 cm in mantle length to carry the Crittercam. However, after capturing three animals and attaching a Crittercam to the back of each, the team then had to wait patiently for the equipment to bob back to the surface after its squid-back ride.

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Back in the lab, Rosen admits that watching the footage of the animals' natural behaviour for the first time was exhilarating: 'A view into this previously secret world was like a dream come true,' she smiles. However, once the initial euphoria had worn off, she had to painstakingly analyse the squids' behaviour. Fortunately, Rosen was not restricted by the lack of colour in Crittercam's black and white recordings. '*Dosidicus gigas* contain only red chromatophores,' explains Rosen, so she knew that dark zones on the animal's skin indicated when the chromatophores were expanded and red, while light regions indicated white colouring. And Rosen adds, 'One of our biggest challenges was finding a way to ensure we were consistently viewing the same spot on a squid when looking for changes in chromatophore activity', so Russell Williams designed software to track individual spots on the swimming squid's body as they changed colour while swimming.

Having catalogued several previously unobserved squid behaviours – including one that the team suspects may be mating – they focused on the animals' colour changes, identifying two specific patterns. The first, 'flashing' – when the animals rapidly switched colour over the entire body surface – was always associated with visual contact with other squid and Rosen suggests that the behaviour could represent a form of squid communication. 'The frequency and phase relationships [synchronisation] between squid during flashing can be changed and this suggests that there is some information being conveyed that makes minute control over these details important to the squid', she says.

The second behaviour that the team identified resembled the flickering patterns of light playing in water near the surface and only occurred when the animals were close enough to the surface for the patterns to be visible in natural light. 'We propose that flickering provides dynamic crypsis [camouflage],' says Rosen, and she suggests that flickering could be analogous to the camouflage adopted by squid that live in shallow waters.

Having discovered that Humboldt squid have tight control over their impressive performance and probably use flashing for communication and flickering for camouflage, Rosen and her colleagues are keen to extend their studies further afield to compare how squid use these colourful displays in other locations and circumstances.

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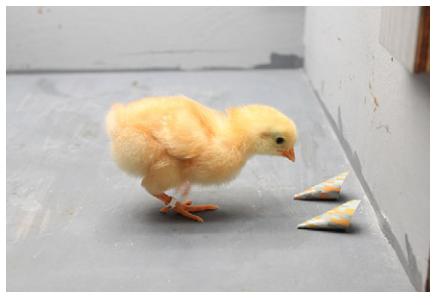
Rosen, H., Gilly, W., Bell, L., Abernathy, K. and Marshall, G. (2015). Chromogenic behaviors of the Humboldt squid (Dosidicus gigas) studied in situ with an animal-borne video package. *J. Exp. Biol.* **218**, 265-275.

Kathryn Knight

Chick colour discrimination worse than expected



Domestic chick colour discrimination test. Photo credit: Peter Olsson.

Few animals put on as good a show as the birds. Strutting about in their bright plumage, no one can fail to be impressed by the rich variety of colour. And, equipped with their large eyes and advanced retinas, birds are believed to have some of the best vision on the planet too. 'We find the highest spatial acuity and the ability to detect very fine patterns [in birds]', says Peter Olsson from Lund University, Sweden. Given the impressive visual abilities of birds, Olsson, Olle Lind and Almut Kelber were curious to find out just how good their colour vision is. Explaining that birds have four colour-sensitive photoreceptors (cones) – compared with our three – which are equipped with light-filtering oil droplets, the team wondered how well chickens are able to discriminate between colours and how their abilities are affected as the light fails (p. 184).

Fortunately, domestic chicks are relatively easy to train – they'll do anything for a peck of seed. Having first trained 48-hour-old birds to recognise a packet of seed that was covered in orange squares, Olsson then tested whether the birds could distinguish the pack that they had been trained to recognise from an empty one that was a different shade of orange or yellow. He also tested how well the birds could distinguish green from blue/green shades. 'The main idea was to test very different types of colours, that way we can make sure that our conclusions are more general' says Olsson. Then he tested how well the chicks were able to distinguish between the coloured packages when he dimmed the lights from levels simulating an overcast day (250 $cd\,m^{-2}$) to moonlight (0.01 $cd\,m^{-2}$).

After weeks of working patiently with the chicks, the team could see that in daylight, the birds were able to distinguish all but the most closely matched of colours. However, as the light failed, the birds began to struggle to distinguish the darkest and most similar colours. And, when the team compared the chicks' performance with that of human volunteers, they were surprised to find that even though the chicks are equipped with more types of photoreceptor than we are (in addition to the rods and colour-sensitive cones that we have, birds also have double cones), their colour discrimination is no better than ours: although Olsson points out that they probably see a broader palette of colours than we do.

Puzzled by the chick's unexpectedly poor performance, the team began to investigate the factors that might restrict their ability to distinguish similar colours in dim light. 'We believe that colour vision is noise-limited,' explains Olsson, who goes on to add that two types of noise are likely to dominate in low light conditions: photon-shot noise, which is due to the random arrival of photons at the retina; and dark noise, where photoreceptors sometimes fire off even though they have not picked up a photon. Adding the two types of noise to an already existing computer simulation of the bird's visual system, the team was able to successfully reproduce the birds' performance in dim conditions and show that both photon-shot and dark noise limit their ability to distinguish between colours when the light is low. 'We needed to include dark noise to explain the intensity thresholds and as far as I know that has not been found before', says Olsson.

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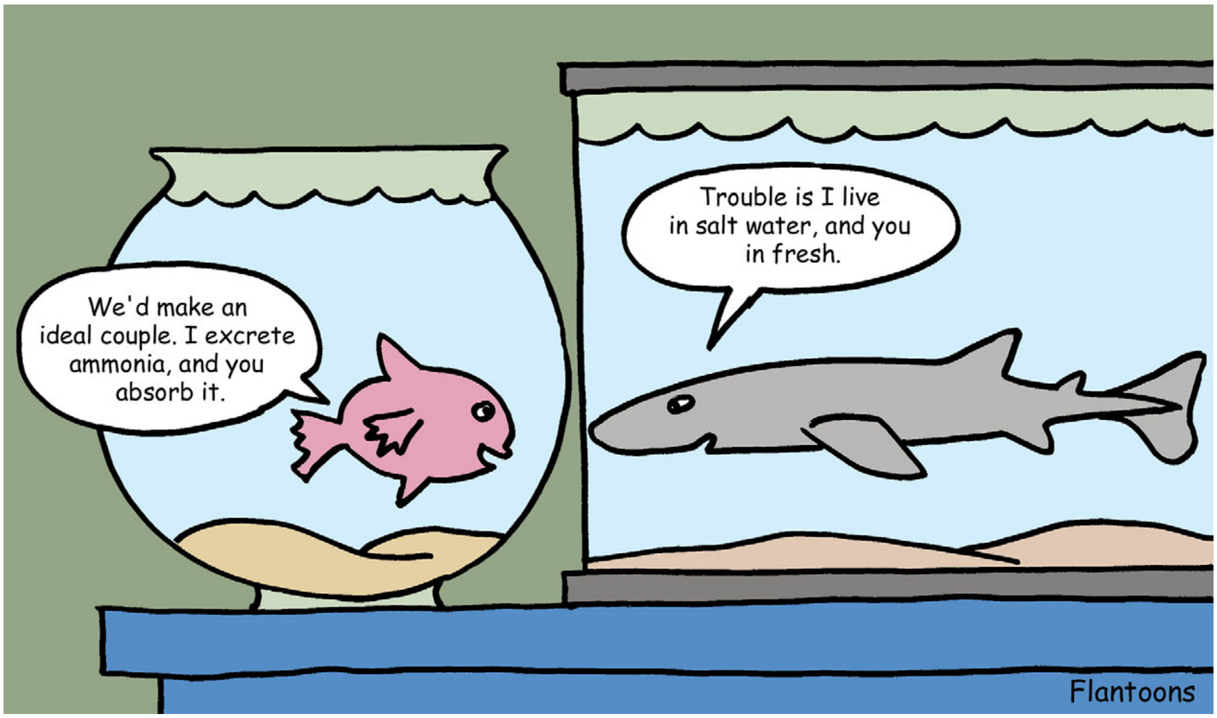
Olsson, P., Lind, O. and Kelber, A. (2015). Bird colour vision: behavioural thresholds reveal receptor noise. *J. Exp. Biol.* **218**, 184-193.

Kathryn Knight

Nitrogen-limited spiny dogfish scavenge ammonia



Most fish get rid of nitrogen waste in the form of toxic ammonia, which is easily disposed of in water. And they get two bangs for each buck as they transport the toxin through Rhesus channels in the gill by importing sodium counter ions in exchange for the excreted ammonia waste. But what about marine elasmobranchs, such as sharks, rays and skates that convert ammonia waste into urea to protect themselves from dehydration in salty water? According to Michele Nawata, Pat Walsh and Chris Wood from the Bamfield Marine Sciences Centre, Canada, it was assumed that these fish wouldn't excrete ammonia across their gills, but it was not known whether they possess ammonia-transporting Rhesus channels in their tissues. Catching spiny dogfish sharks in the sea off British Columbia, the trio tested the animals' responses to environmental ammonia (p. 238).

Measuring ammonia excretion across the gill under normal conditions, the team was unsurprised to find that it was low, ensuring that the fish retained sufficient ammonia for urea production. However, when environmental levels of ammonia were high, the shark unexpectedly began taking ammonia on board and also increased urea production – although the animals were unable to store the excess urea so their urea excretion rates increased also. And when the team compared the dogfish's expression of Rhesus channel genes and enzymes involved in ammonia excretion with the expression patterns in freshwater bony fish, they found that the shark altered both expression patterns, but in different ways from the freshwater animals.

Having found that the dogfish's responses to high environmental ammonia differ radically from those of freshwater species, the team admits that they were surprised that dogfish appear to be able to extract ammonia from their surroundings. They say, 'we propose that the gill of this nitrogen-limited predator is poised… to scavenge ammonia-N from the environment during high environmental ammonia to enhance urea-N synthesis'.

doi:10.1242/jeb.118547

Nawata, C. M., Walsh, P. J. and Wood, C. M. (2015). Physiological and molecular responses of the spiny dogfish shark (*Squalus acanthias*) to high environmental ammonia: scavenging for nitrogen. *J. Exp. Biol.* **218**, 238-248.

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