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Inside JEB

LET'S STICK TOGETHER: PIGEON HOMING IN PAIRS


Zsuzsa Ákos

There's no place like home – no doubt a sentiment that any homing pigeon would agree with. These talented pigeons can be released far away from their loft and yet quickly develop, and remember, distinct homeward-bound routes. For many years, scientists have been releasing these intelligent birds individually to determine exactly how they develop these stable routes. While much progress has been made by these solo releases, Andrea Flack, a PhD student from the University of Oxford, UK, points out that pigeons 'are clearly attracted to each other when they navigate and have a strong tendency to fly in flocks.' So, with the help of Robin Freeman from University College London, UK, and her other two co-supervisors, Tim Guilford and Dora Biro from Oxford, Flack decided to see how well pigeons would learn to navigate in small flocks. (p. 1434)

First the team decided to test the navigational skills of pigeons released in the smallest flock size, releasing eight pairs of pigeons at a site 7 km away from their roost. 'We suspected that pairwise-trained birds would behave similarly to individuals and that they would develop routes, but we didn't know how they would develop their routes, or whether they would develop them faster or slower', recalls Flack. At first, it seemed as if the birds might not co-navigate home together, with the pairs frequently splitting up while homing. However, by the third release, the birds perhaps became less wary of their assigned companion and started to home together. After six releases the winged duos had established stable flight paths, which had, in the end, developed just as quickly as in individually released birds.

After the birds had settled into the habit of homing as pairs, the team then challenged the pigeon by increasing the size of the flock, releasing them with another pair. Flack explains that 'If you pair up individually trained birds, then you find these interesting outcomes; sometimes one individual leads the other along its own route, other times they fly along a compromise route.' Are birds trained in pairs as equally amenable to adjusting their routes when flying with others? The results suggest that training in pairs actually promotes compromise, with these birds flying along a middle-ground path more frequently than singly trained birds. Whereas individually trained birds will only compromise if their respective paths were less than 600 m away, pairwise-trained birds compromised even when the two routes lay at a distant 1.5 km away. Homing birds rely on landmarks to guide them home and singly trained birds might compromise when routes are within visual range of their guiding landmarks. Flack suggests that pairwise-trained birds may be more willing to compromise at farther distances by relying less on landmarks for reassurance and instead drawing comfort from the presence of their training partner. Certainly, when the team looked at how closely the four-birded flock flew, they did find that pairs stuck together and flew closer to their partner than to the other pair.

Despite overall increased compromise in pair-trained birds, some combinations did fall into a leader–follower pattern, with some pigeon pairs emerging more frequently as leader pairs. It is possible that these leader pairs preferred to lead because they weren't able to draw as much confidence from their partnership with the other pair, and still preferred to rely more on landmarks. Either way, regardless of whether the pairs compromised, Flack's study clearly highlights the important role that social bonds between birds play on collective decisions taken by flocks. This give-and-take attitude has its benefits, with the team finding that homing efficiency increases in flocks. So, sticking together is worth it!

10.1242/jeb.086249

Flack, A., Freeman, R., Guilford, T. and Biro, D. (2013). Pairs of pigeons act as behavioural units during route learning and co-navigational leadership conflicts. *J. Exp. Biol.* **216**, 1434-1438.

Nicola Stead

COPING WITH OCEAN ACIDIFICATION

Our appetite for fossil fuels and our increasing carbon footprint is having a dramatic impact on our environment, not least in our oceans, where excess carbon dioxide is absorbed and reacts with water to form carbonic acid. 'At first scientists thought this was a good thing because the ocean would take that carbon and sequester it away from the atmosphere, but it turns out that in the process of doing that, carbonic acid is changing the pH of the ocean', says Jonathon Stillman, a researcher at San Francisco State University, USA. With our oceans gradually acidifying, how will marine organisms cope? Stillman realised that the intertidal porcelain crab would be the perfect organism with which to study the affects of acidification; he explains why: 'embryonic crabs are brooded in the intertidal

zone, where the habitat is very dynamic with lots of [natural] variability in pH. Then the embryos hatch into larvae and swim offshore into an environment that is more stable, before they settle back into the variable intertidal zone as juveniles.' With embryos and juveniles growing in variable pH environments, do they cope better with low pH than larvae, which are used to stable environments? If so, what physiological changes are associated with this pre-adaptation to lower pHs? Stillman recruited two eager Master's students, Lina Ceballos-Osuna and Hayley Carter, to find out (p. 1405 and p. 1412).

As the lab had never worked with early life stages before, the two students first had to establish how to maintain the embryos, larvae and juveniles. Stillman recalls that this was no small feat as the embryos are the size of a poppy seed and while the larvae are relatively long at 1 cm, they have long spines covered in tiny little hooks. These barbed spines meant that the larvae tended to get stuck in pipettes or the mesh used in their storage chambers. However, with guidance from both Stillman and Nathan Miller, a post-doc in the lab, the pair quickly overcame these hurdles, and began investigating how various physiological aspects changed when the water pH was reduced to pH 7.6. Between the two students, they characterised an impressive array of traits in acidic conditions with Ceballos-Osuna looking at survival rates and cardiac performance, amongst others, and Carter focusing more on determining changes in metabolism and energetics.

Overall, the two lead researchers reached broadly the same conclusion, as Stillman remembers: 'different life stages did not, on average, respond to pH differently, so the effect of low pH on the embryos, larvae and juveniles was similar. On average, low pH tended to reduce their metabolic performance, they had lower heart rates and they had lower oxygen consumption rates.' In addition, larvae, whose habitat tends to have a stable ambient pH near 8, did not seem to be worse affected than the embryos or juveniles.

Unlike their initial theory, it seemed that in fact all life stages seemed to do worse when maintained in more acidic conditions. However, this wasn't the only unexpected result, as Stillman hints: 'So what we didn't set out to study in the beginning, but what turned out to be our most interesting finding I think, had to do with the way we did our experiments.' He goes on to explain that, although easier for handling purposes, the team did not mix broods from multiple mothers. This meant that broods originating from one mother were kept separate from other broods. When the team came to do their measurements they knew exactly which mother the embryos or larvae had come from. While overall measurements indicated that metabolic performance was decreased in acidic conditions, they found that in fact some broods weren't as affected and some even had higher metabolism under low pH. 'That finding was unexpected and is extremely important because it says that there is a lot of variation within a species in terms of how an organism will respond to future low pH', says Stillman. So, while on average embryos and juveniles might not be pre-adapted to living in a more acidified marine environment due to their life history, there is scope within the species as a whole for adaptation to acidified conditions, and some of these young crabs will have increased tolerance for low pH. So, there is still hope of finding these crabs in rock pools when exploring the shore in years to come.

10.1242/jeb.086728

Ceballos-Osuna, L., Carter, H. A., Miller, N. A. and Stillman, J. H. (2013). Effects of ocean acidification on early life-history stages of the intertidal porcelain crab *Petrolisthese cinctipes*. *J. Exp. Biol.* **216**, 1405-1411.
Carter, H. A., Ceballos-Osuna, L., Miller, N. A. and Stillman, J. H. (2013). Impact of ocean acidification on metabolism and energetics during early life stages of the intertidal porcelain crab *Petrolisthes cinctipes*. *J. Exp. Biol.* **216**, 1412-1422.

Nicola Stead

GILA MONSTERS NEED TO BINGE DRINK FOR HYDRATION

There's nothing like a nice tall, cool glass of water on a hot summer's day, but for animals living in hot and parched deserts, free- standing water is hard to come by and these animals have to find other ways to keep hydrated. Some reduce movement altogether to save water lost from evaporation, and instead fend off dehydration by relying on fluid stored in their urinary bladders. Others are able to remain active and extract water from their diet. Given that most meaty meals contain up to 70% water, Christian Wright, along with his supervisor, Dale DeNardo, and colleague Marin Jackson, from Arizona State University, USA, wondered whether the carnivorous Gila monster, *Heloderma suspectum*, could rely solely on its juicy diet of vertebrate nestlings and eggs for all its water needs during the dry season (p. 1439).

Mimicking pre-summer conditions found in the wild, the team first allowed 12 adult Gila monsters to drink as much water as they wanted. As the team already knew that Gila monsters are able to use water stored in their urinary bladders, they first drained the Gila monsters' bladders before simulating the hot and arid summer conditions, keeping them at 30°C for the duration of the experiment. By taking weekly blood samples and measuring osmolality (a measurement of the ratio of solutes to water), the team could determine how dehydrated the lizards were. Upon reaching a mildly dehydrated state, some of the thirsty lizards were presented with a tempting juicy juvenile rat, in the hope that this would slow down their dehydration. However, they dehydrated just as quickly as their unfed friends, and after 32.5 days all the lizards had reached extreme dehydration – a state that they experience naturally by the end of the seasonal drought. Even the provision of another meal at this stage did not significantly rehydrate them.

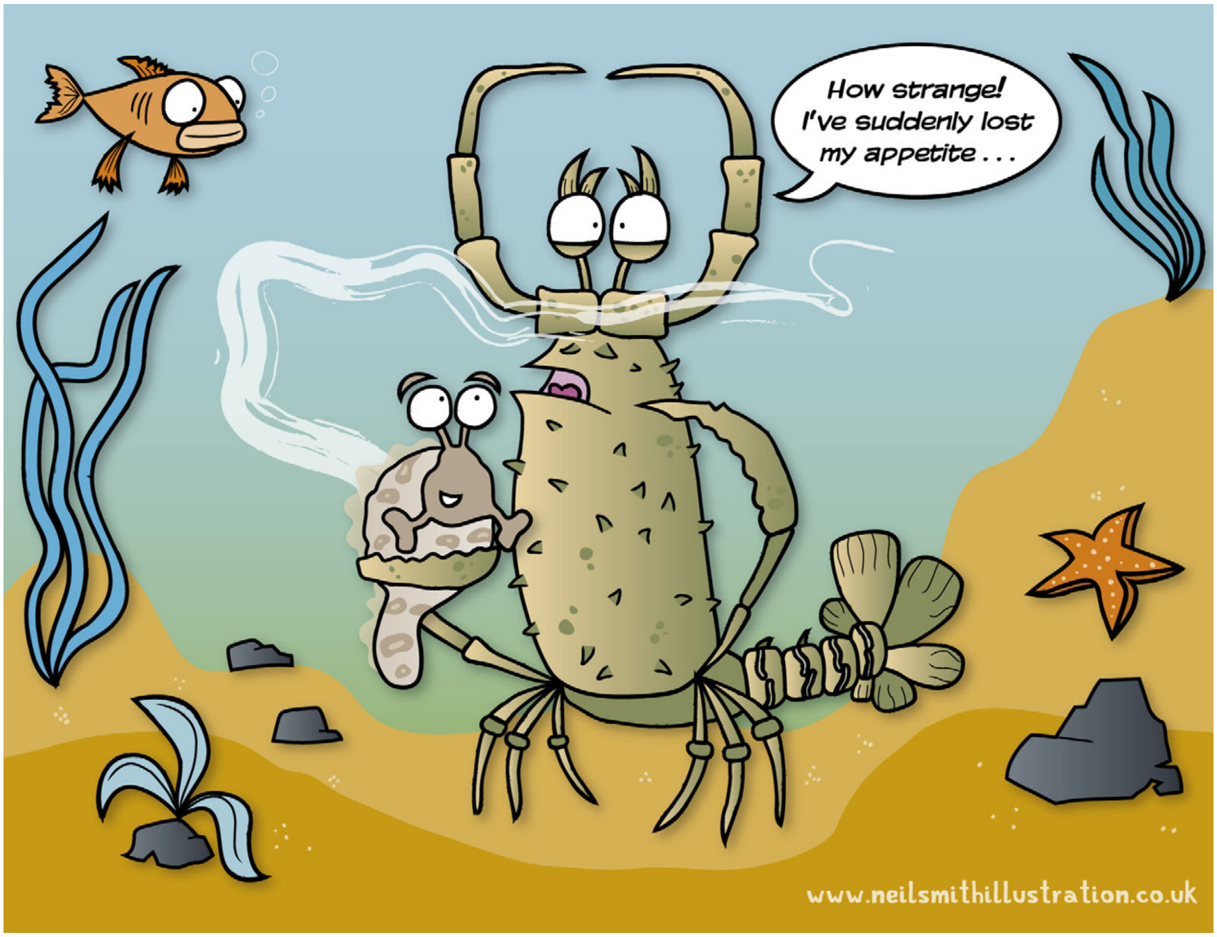
Next, the team repeated the experiment adding in an extra meal at the beginning. This time, the team took blood samples 6 h, 24 h and 48 h after meal consumption to check for immediate changes in osmolality. While the extra meal allowed the lizards to last an extra 10 days before becoming extremely dehydrated, the team still found that water from food was not sufficient for the lizards' water needs. In fact, blood osmolality increased after feeding, suggesting that significant amounts of water were used during digestion. The water gained from digestion did not recuperate these initial water costs. However, when the team presented the parched lizards with 42 ml of water – the equivalent of the amount found in their final meal – osmolality significantly decreased, improving the animals' hydration. It is likely that despite their water-rich, meaty diets, Gila monsters rely solely on the water stored in their bladders after pre-summer rains, without which they dehydrate quickly.

10.1242/jeb.086975

Wright, C. D., Jackson, M. L. and DeNardo, D. F. (2013). Meal consumption is ineffective at maintaining or correcting water balance in a desert lizard, *Heloderma suspectum*. *J. Exp. Biol.* **216**, 1439-1447.

Nicola Stead

STICKY SECRETIONS SAVE SEA HARES FROM PREDATORS



Sea hares are not the favourite food choice of many marine inhabitants, and it's easy to see why when you find out about the chemical weapons they employ when provoked – namely, two unpalatable secretions, ink and opaline, which they squirt at unsuspecting peckish predators. However, while much is known about the consequences of purple ink secretion, how the whitish and viscous opaline outsmarts a potential predator remains unknown. Charles Derby from Georgia State University, USA, wondered whether opaline could decrease the activity of a predator's sensory system. Along with his colleagues Tiffany Love-Chezem and Juan Aggio, he set out to test the effect of opaline on spiny lobsters, which occasionally try to snack on sea hares. The investigating trio decided that they would determine how opaline affects the chemosensory and motor neurons found in lobster's antennules, which are both activated by food odours and essential for the motivation and ability to feed (p. 1364).

To begin, they extracted the water-soluble fraction of opaline, and although this lacks the amino acids and other chemical attractants that make up opaline, it is nonetheless just as sticky and possesses the physical properties of opaline. The team then painted this sticky, water-soluble fraction onto the tips of the lobsters' antennules before presenting them with tasty smelling 'shrimp juice' and measuring electrical activity in both chemosensory and motor neurons. Unlike lobsters with clean, gunk-free antennules, the shrimp juice failed to whet the appetite of opaline-treated lobsters, with the response of chemosensory and motor neurons being significantly reduced.

The team next wondered whether the amino acids present in opaline could also dampen neuronal activity. Mixing together the five most prominent amino acids found in opaline, they again painted the antennules and tempted the lobsters with the scent of shrimp juice. This time, however, the neurons fired robustly in reaction to the delicious shrimpy aroma. When the amino acids were mixed with the sticky substance carboxymethylcellulose, the neuron reactions were again inhibited. Furthermore, carboxymethylcellulose alone also stopped neurons firing. So, it seems that stickiness is the key to blocking neurons and allowing the sea hare to escape, while the lobster cleans itself.

10.1242/jeb.085951

Love-Chezem, T., Aggio, J. F. and Derby, C. D. (2013). Defense through sensory inactivation: sea hare ink reduces sensory and motor responses of spiny lobsters to food odors. *J. Exp. Biol.* **216**, 1364-1372.

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