INSIDE JEB

Soil-churning echidnas essential for Australian environment

A short-beaked echidna. Photo credit: Christine Cooper.

Australia may not immediately spring to mind as your archetypal Noah's ark, but the list of native creatures that make their homes on the vast continent reads like an encyclopaedia of Gondwanaland species, ranging from monotremes to marsupials. Of the five surviving monotremes, platypuses and short-beaked echidnas are the only two that make their homes in Australia and although little is known about the life-styles of either one, Christine Cooper, from Curtin University, Australia, and Phil Withers, from the nearby University of Western Australia, are beginning to uncover details about the echidna's physiology. So when Cooper and Withers invited Chris Clemente, from the University of the Sunshine Coast, Australia, to hop on the back of their echidna fieldwork to learn more about the animals' day-to-day antics, Clemente jumped at the offer.

'I had these little accelerometers that I had got from the University of Queensland', says Clemente, who admits that when Cooper and Withers suggested teaming up he was having a frustrating time attaching them to the backs of lizards that promptly vanished into the bush. Would the echidnas prove more cooperative? Within a few weeks, he found himself driving with Cooper and Withers to the Dryandra Woodland to track the spiky monotremes, and this time his patience was rewarded. Despite searing daytime temperatures of 45°C and the echidnas hunkering down for lengthy periods in caves, the team was able to retrieve the trackers successfully. 'And when I went back and looked at the data, it was fantastic', laughs Clemente. The only drawback was the tracker's short (24 h) battery life, so Clemente collaborated with University of Queensland engineers Surya Singh and Philip Terrill to redesign them. 'The [new] sensors were very small, about the size of a postage stamp', says Clemente, recalling how Craig Freakley individually hand-soldered each component onto the new chips using a microscope and minute soldering iron. Returning with the redesigned trackers to Dryandra 18 months later in the spring with Cooper, Withers and Freakley, Clemente filmed the echidnas so that they could correlate the accelerometer traces with specific echidna behaviours to get a handle on the private lives of the elusive animals.

Recalling that the temperature difference between the summer and spring was about 25°C, Clemente says, 'I was interested in how echidna activity changes with these differences and we found that there is a huge effect'. During spring, the animals waddled around at a stately 0.3 m s^{-1} for much of the day. However, when the temperatures rocketed, the animals dramatically reduced their activity to a couple of hours in the morning and, instead of walking, they sprinted everywhere at their top speed of around 0.6 m s^{-1}; 'They certainly try to avoid really hot temperatures', says Clemente.

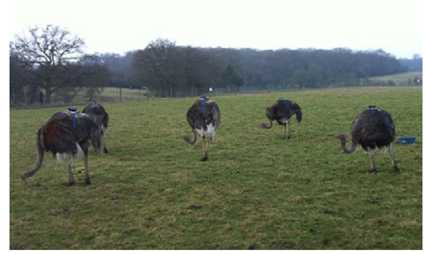
During the first field trip, he had also noticed a lot of digging scars in the ground where the animals had been prospecting for their favourite snacks – juicy termites. Wondering how much of an impact the animals' excavations might have on the environment, Clemente was impressed to see that they invested as much as 10% of each day in digging. And when he calculated how much soil an individual could shift in a year, it was an impressive 200 m^3; 'so if you have 12 echidnas, they are moving the volume of an Olympic-sized swimming pool of dirt a year, which is quite a lot', laughs Clemente. And he suspects that the echidna's monumental earthworks could have profound implications for Australia's environmental health. Explaining that the echidna is one of the few native burrowing species surviving in Australia and that burrowing animals are essential for aerating soil and mixing in organic material, Clemente says, 'They are probably one of the last really big bioturbators [soil mixers] left in Australia, which means that they are really important for the environment'.

10.1242/jeb.150185

Clemente, C. J., Cooper, C. E., Withers, P. C., Freakley, C., Singh S. and Terrill, P. (2016). The private life of echidnas: using accelerometry and GPS to examine field biomechanics and assess the ecological impact of a widespread, semi-fossorial monotreme. *J. Exp. Biol.* **219**, 3271-3283.

Kathryn Knight

Ostriches specialised for economic running



Ostriches wearing tracker backpacks. Photo credit: Anthony Channon.

When humans and other animals walk, jog or run, most fall into a comfortable pace that they can sustain for lengthy periods. Monica Daley, from the Royal Veterinary College (RVC), UK, explains that animals appear to conserve energy when moving, selecting the most efficient style of movement – gait – that matches the speed at which they travel. However, most of the studies that have investigated why animals switch from one gait to another have analysed the movements of animals on laboratory treadmills. 'We wanted to explore whether we could start trying to bridge the gap from laboratory work to field-based study', says Daley, who is keen to understand how animals select their movements in their natural

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environments. However, instead of choosing to analyse the movements of a diminutive species with an even temperament, Daley, Anthony Channon and undergraduate Grant Nolan opted to investigate the movements of a flock of ostriches.

Despite the bird's fearsome reputation, Ola Birn-Jeffery had become mother to a flock of 12 ostrich chicks during her PhD at RVC, and Daley recalls how local ostrich farmer, Scott Dyason, had trained Birn-Jeffery in ostrich wrangling before she took charge of the youngsters. However, the ostriches weren't always as cooperative as Daley would have liked. Although they were content for Channon and Nolan to strap boxes containing the GPS tracker and accelerometers to their backs and to saunter around the enclosure, the team could never persuade them to go faster than a gentle trot, even though they can easily outrun a human. Eventually, Channon and Nolan resorted to chasing the ostriches on quad bikes to get them to shift into top gear.

Having finally recorded the ostriches roaming around their paddock over their full range of speeds, Daley was faced with the task of analysing 30,000 strides. And when the server carrying the colossal data set crashed, the project was in serious jeopardy until Jade Hall painstakingly pieced the information back together. Despite the setbacks, Daley eventually identified that the switch from a walk to a run was characterised by a specific shift in the accelerometer signals, which allowed her to reliably identify the transition and specify exactly how the birds were moving at all times.

Analysing the movements, she noticed that all of the birds walked over a very narrow range of slow speeds around 1 m s^{-1}, which was surprising, because humans (another biped) walk over a much wider range of speeds. In contrast, the birds' running speed range was immensely broad, 1.4 m s^{-1}– 11.3 m s^{-1}. Daley explains that most animals have a narrow range of speeds over which they walk or run and these speeds occur when the energetic cost of the movement is lowest. However, the energy cost of running remains remarkably constant over a wide range of speeds for the ostriches, and Daley says, 'Ostriches are exceptionally well specialised for economic running'.

In addition, Daley analysed the speeds at which the birds shifted up into a run or broke into a walk as they slowed, and she was intrigued to see that they were different. 'If the animals are choosing gaits solely based on energy costs, you wouldn't expect this gait transition hysteresis', says Daley, who suspects that other factors contribute to the animals' choice of movement as they speed up and slow down. However, she admits that she is pleased that the measurements of the ostriches' preferred speeds as they roam around agree well with those that have been collected in the laboratory.

10.1242/jeb.150193

Daley, M. A., Channon, A. J., Nolan, G. S. and Hall, J. (2016). Preferred gait and walk–run transition speeds in ostriches measured using GPS-IMU sensors. *J. Exp. Biol.* **219**, 3301-3308.

Kathryn Knight

Pacific spiny dogfish successfully scavenge ammonia from sea

Pacific spiny dogfish, *Squalus suckleyi*. Photo credit: Gudrun De Boeck.

Going hungry is not an uncommon experience for most species, and Chris Wood, from the University of British Columbia, Canada, says that many Pacific dogfish often have empty bellies. However, while most animals consume protein for growth and tissue repair, sharks also require protein to continually replenish urea in their tissues, which prevents the fish from drying out in seawater, but is constantly leached from their bodies. So when Wood and colleagues discovered that dogfish can absorb ammonia at exceptionally high concentrations (1000 μmol l^{-1}) through their gills from the surrounding water for conversion into urea, he wondered whether the fish may be able to extract sufficient ammonia from seawater with lower ammonia concentrations (200 μmol l^{-1}), more typical of those near the coast, to supplement their urea supply.

Immersing Pacific spiny dogfish that had been caught in Barkley Sound in seawater containing ammonia ranging from 100 to 1600 μmol l^{-1} over a 10 h period and plotting the animals' ammonia uptake rates, Wood and Marina Giacomin realised that the plot had the characteristic shape of a biological process driven by active transport through protein channels, instead of simple diffusion into the body. And when the duo calculated the ammonia concentration at which the uptake rate was half of the maximum value, they ended up with a value of 379 μmol l^{-1}, 'indicative of the normal concentration range within which the system evolved to operate', they say. The duo also compared the fish's ammonia uptake rates with the rate at which they lost urea to their surroundings, and it was clear that the fish were benefiting from a net influx of the gas. They also suggest that ammonia scavenged from the sea over the length of time that it would take a small (1 kg) shark to digest a fish meal could provide as much nitrogen as 9 g of digested muscle; enough to supplement one-third of the urea lost to the environment through the gills over the same period.

Intrigued by the various transport mechanisms that the fish may use to absorb ammonia through their gills, Wood and Giacomin tested several alternatives and concluded that the gas is likely carried by Rhesus proteins – channels that are known to carry ammonia gas molecules across cell membranes. The duo also suggests that the fish may be able to actively pump sufficient gas into their blood for urea production to tide them over until they catch their next fish dinner.

10.1242/jeb.150201

Wood, C. M. and Giacomin, M. (2016). Feeding through your gills and turning a toxicant into a resource: how the dogfish shark scavenges ammonia from its environment. *J. Exp. Biol.* **219**, 3218-3226.

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