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Sweating doves keep cool at 60°C

A white-winged dove in southern New Mexico, USA. Photo credit: Matt Baumann.

Birds tend to run hot. With their higher metabolic rates and feather insulation, their body temperatures are routinely up to 41°C. But with estimates suggesting that 2015 could be the hottest year on record and with extreme thermal events on the increase, no one is sure how our feathered friends will fare in the future. 'These [extreme] events produce direct mortality in birds, megabats and other wildlife on several continents', says Eric Smith from the University of New Mexico, USA. Concerned about the impact of environmental change on desert bird populations, Blair Wolf and a team of international collaborators from Australia, South Africa and the USA, have started investigating the effects of extreme heat on birds and how environmental change will affect which habitats they occupy. Knowing that birds lose heat from their bodies by evaporating water, either while panting or directly across the skin, Wolf, Smith and Alexander Gerson decided to investigate the thermal tolerances and water losses of three desert species.

Relocating the lab to the deadly Sonoran Desert – where temperatures can reach a scorching 49°C – Smith, Gerson, Wolf and undergraduate Jacqueline O'Neill lured Gambel's quails and two species of dove (mourning doves and white-winged doves) into traps laced with grain. Then, they gently placed individual birds in a respirometry chamber housed in a modified ice chest where they could precisely regulate the air temperature while recording the birds' water losses and metabolic rates as they gradually increased the temperature from a comfortable 30°C to temperatures exceeding 60°C. 'Some birds showed varying levels of activity from resting quietly to intermittent flapping escape attempts', Smith recalls. However, he admits that he was astonished when the first mourning dove that they examined at the blistering temperature of 60°C appeared perfectly content; 'it was an incredible sight', he says.

Analysing the birds' metabolic rate traces relative to the ice chest temperature, the team realised that the doves were much better prepared for a hotter future than the quails. The doves' metabolic rate increased dramatically at temperatures above 45.9–46.5°C as they dealt with the physical burden of the heat, while the quails' metabolic rate began rising significantly at the lower temperature of 41.1°C. And when they investigated the birds' weight-adjusted water loss rates, they could see that the doves lost 30–45% more water than the quails to keep cool. 'Higher rates of evaporation and higher upper critical temperatures made the doves exceptionally heat tolerant, allowing them to maintain body temperatures at least 14°C below air temperatures as high as 60°C', says Smith.

Explaining that most birds, quail included, actively pant to lose heat, Smith says, 'Panting is metabolically costly and produces its own heat'. However, doves lose water by evaporation across the skin, and Smith suspects that this could tip the doves a metabolic advantage. 'Evaporating water from the skin appears to have negligible metabolic costs', he explains, adding that the passively evaporating doves can dissipate heat loads that are greater than three times their own thermal output, whereas panting quail can only deal with heat loads double theirs.

However, he adds that doves do pay a price for their ability to withstand the heat. 'Doves…support a high-water-use "lifestyle" that could reduce their abundances if water were unavailable', he explains, adding, 'It is critical that we understand the thermoregulatory and water balance challenges that birds face in a rapidly warming world…it is a prerequisite for understanding avian distributions now and in a warmer future'. Who knows, maybe doves will inherit the Earth after all.

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Smith, E. K., O'Neill, J., Gerson, A. R. and Wolf, B. O. (2015). Avian thermoregulation in the heat: resting metabolism, evaporative cooling and heat tolerance in Sonoran Desert doves and quail. *J. Exp. Biol.* **218**, 3636-3646.

Kathryn Knight

Fleas don't cope in burrowing host's stale air

A female *Xenopsylla ramesis*. Photo credit: Michael W. Hastriter.

Most fleas have it made. Riding around on their hapless hosts, the parasites are safe and warm with an almost limitless supply of food on tap. But not all parasites are quite so lucky. Cynthia Downs from Hamilton College, USA, explains that the surroundings may be less wholesome for fleas that hitch a ride on species that live in burrows where the carbon dioxide levels can rocket. 'I was interested in how environmental conditions affect host–parasite interactions', explains Downs, remembering how her interest in the effects of carbon dioxide was triggered while working in Berry Pinshow's lab in Ben-Gurion University of the Negev, Israel. 'They were investigating how burrow geometry affects concentrations of CO_2 in burrows and the physiology of rodents', says Downs. Learning that high concentrations of CO_2 in air can affect the immune response of mammals, Downs wondered how parasitic hitchhikers may be affected by the stale subterranean air produced by their hosts.

'I wanted to determine how concentrations of CO_2 that mimic those found in some burrows where fleas reside affected how fleas interacted with their hosts,' says Downs. Working with Irina Khokhlova,

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Downs carefully mixed CO_2 with air to reproduce the atmospheric conditions that have been measured in the tunnels of some burrowing species and then pumped the modified air into the airtight plastic cages of burrowing Sundevall's jirds to simulate the atmosphere below ground. 'Overall, the jirds are fairly docile and very easy to work with', recalls Downs, but she admits that she had to overcome her natural squeamishness about plunging her hand into a box of *Xenopsylla ramesis* fleas before transferring them to the rodents – even though the fleas do not bite humans.

Explaining that the fleas spend only a fraction of their lives riding on their hosts – only hopping onto a passing rodent for 3- to 6-day periods when they need to feed and reproduce – Downs and Khojhlova replaced the rodents' population of 150 fleas every 3–6 days, counting the survivors to calculate the survival rate. And when they compared the fleas' death rate with that of fleas from jirds in a normal atmosphere, they found that it rocketed, with 27% more fleas dying in the stale air. The simulated-burrow fleas also produced 0.3 eggs per female less than the fleas that were basking in fresh air. And when the duo tested how well the fleas coped after abandoning the host and hunkering down in the improvised burrow's sand for several days, they found a similar increase in the death rate. The high-CO_2 fleas were also less keen on escaping. 'Fleas don't tolerate living in a high fractional concentration of CO_2 used in this experiment very well,' says Downs. 'I expected to see a small decrease in survival…but I didn't expect to see a decrease in reproductive success', she adds.

So instead of being prepared for their subterranean existence, *Xenopsylla ramesis* fleas are significantly compromised by their high-CO_2 lifestyle. Downs suggests that the burrow fleas may hold their breathing tubes (spiracles) open for longer than fleas in a normal atmosphere, causing them to dry out faster and die. She also says, 'They probably experience many CO_2 conditions in their natural environment', explaining that the fleas are happy to infest many other rodent species, which has probably prevented them from adapting to the burrow's stale atmosphere, while possibly providing a little relief for the burrowing rodents from scratching at their uninvited guests.

10.1242/jeb.133611

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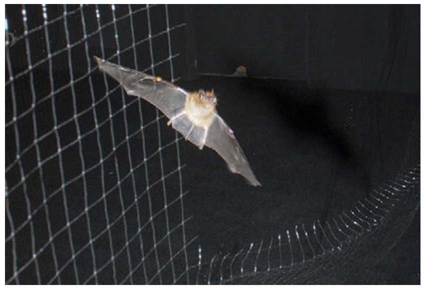
Kathryn Knight

Bats coordinate echolocation calls with wing beats



Big brown bat negotiating net obstacle. Photo credit: Ben Falk.

Bats are the ultimate evolutionary opportunists. To cash in on the bonanza of insects that take to the air after dark, the mammals have developed agile flight and a unique echolocation system to locate fast-moving bugs in the dark. However, Benjamin Falk from Johns Hopkins University, USA, explains that although bat flight and echolocation had been studied extensively, they had never been investigated simultaneously: wind tunnels are too noisy to record echolocation calls and the animals' natural movements were too complex to analyse as they flew freely. That was until 3D motion capture technology became available. The sophisticated system allows scientists and Hollywood directors to reproduce complex natural movements for research and the movies. So, when Cynthia Moss acquired 10 motion-tracking cameras while Falk was in her lab at the University of Maryland, USA, the scene was set for him to find out more about how nimble bats coordinate their echolocation calls with flight.

But first Falk had to find bats that were keen to fly for him. Fortunately, big brown bats (*Eptesicus fuscus*) often make their homes in attics and their human landlords are perfectly happy for Falk to rid them of the uninvited guests. And, once the bats were settled in the lab, Falk recalls that they were very cooperative. 'They are very food motivated', he chuckles, explaining that they soon learned to negotiate a series of net obstacles in return for a mealworm reward suspended in the middle of the room. Designing a course where the bats had to make a sharp turn through a hole in one net before climbing steeply and turning through a hole in a second net, Falk and Joseph Kasnadi then gently attached 13 reflective dots at specific locations on the bats' wings and bodies before filming their flights with the motion-capture system while recording their echolocation calls.

'The first major hurdle was figuring out how to analyse all of the motion-tracked data from the reflective markers', says Falk, who had to painstakingly reconstruct the bats' movements from the trajectory of each reflective dot. 'Then we could look at how the wings and body moved together and connect that to the echolocation calls', Falk recalls. Having meticulously reconstructed the motions and echolocation calls from almost 250 flights, Falk could see that the animals flew fast towards the first net ($4.15\ m\ s^{-1}$) before dropping their speed and turning hard through the first hole. Then they climbed at $2.8\ m\ s^{-1}$ up to the second hole before turning through it at $207.5\ deg\ s^{-1}$ to intercept the mealworm treat. And when Falk analysed the timing of the echolocation calls relative to each wing beat, he saw that the echolocation calls tended to coincide with wing's upbeat.

Explaining that bats usually exhale during the up-stroke of a wing beat, Falk says, 'The bats emit these sounds in time with their wing beats to take advantage of the respiration cycle…they are basically able to produce these sounds with no energetic costs'. However, the bats were able to shift the timing of their echolocation calls to later in the wing beat when turning. Falk also noticed that instead of clustering calls as they turned corners, the bats produced more clustered calls while flying straight, suggesting that the call pattern is not a by-product of the turning movement.

Having shown that bat echolocation calls are tightly coordinated with their flight pattern, although they can adapt their call patterns to suit a manoeuvre, Falk is keen to learn about how bats cope with gusts of wind.

10.1242/jeb.133595

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Anosteocytic tilapia bones rebuild

We tend to take our bones for granted: they are constantly modified in response to use and their remarkable ability to repair damage is really only apparent after a painful break. But spare a thought for other less fortunate animals that lack the specialised cells, osteocytes, that are essential for bone rebuilding. Ron Shahar from The Hebrew University of Jerusalem explains that osteocytes detect when a bone is experiencing a mechanical load and trigger the adaptation that strengthens it in response to changes in use. However, he and his team explain that many fish lack these essential cells, posing the question whether fish bones can be modified at all and if so, how do they sense the mechanical loads that trigger the alteration?

Inserting two screws into the bony opercula (gill cover) of tilapia and linking them with a spring – to pull the screws together and mechanically load the bone – Ayelet Atkins monitored how the bone responded over 50 days. She found that the bone between the spring-loaded screws dramatically altered structure, showing evidence of high numbers of bone-altering osteoblasts and osteoclasts that accompanied bone resorption and deposition in the vicinity of the spring, which resulted in a stiffer region of bone that also changed its shape.

'We show that the bone of the anosteocytic tilapia is able to adapt to applied loads, despite the complete absence of osteocytes', says Shahar and his team suggests that osteoblasts could be the cells that detect mechanical loading in fish bones that lack osteocytes.

10.1242/jeb.133587

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