© 2017. Published by The Company of Biologists Ltd | Journal of Experimental Biology (2017) 220, 4081-4083

INSIDE JEB

Andean and Tibetan birds crack breathing in different ways

Andean goose and chicks. Photo credit: Kevin G. McCracken.

Set a group of engineers a problem and each individual will often come up with their own solution, while on other occasions, several individuals may produce the same solution from different starting points; even evolution adopts both strategies. So, when Sabine Lague, Tony Farrell and Bill Milsom began wondering how birds have adapted to life at high altitude, it wasn't clear whether species with different lifestyles had opted for the same strategy, or other alternatives. 'High-altitude environments pose a significant physiological challenge for animals; they are typically colder, drier and all of them have less available environmental oxygen', says Lague. So, would birds that live permanently in thin air use the same strategy to supply sufficient oxygen as migratory species, which only venture to high altitudes during transit? Lague, Milsom and Beverly Chua ventured to the Andes and onto the Tibetan plateau to investigate the question.

Working with Yuxiang Wang and Yang Zhong in Tibet, and Kevin McCracken, Peter Frappell, Graham Scott and Luis Alza in Peru, Lague and her colleagues collected bar-headed geese from Lake Qinghai (3200 m), and Andean geese and crested ducks from altitudes over 4000 m in the Andean mountains before allowing the South American birds to adapt to the same altitude as the Tibetan birds. Once the birds had adjusted, the team gently restrained the animals before adding nitrogen to the birds' air to reduce the amount of oxygen in order to simulate ascents from 3300 m to 4500, 7000, 8500 and 11,000 m while recording the birds' oxygen consumption, how much air they inhaled, how fast and hard their hearts were beating and the amount of oxygen carried in their blood.

As the oxygen thinned, the bar-headed geese breathed harder, inhaling twice as much air at the highest simulated altitude; however, neither of the Andean species increased their breath rate or the volume of air inhaled. And when the team compared the performances of the hearts of the three species, they all managed to pump more blood as the oxygen became scarcer, but the bar-headed geese increased their heart rate while the South American birds pumped a larger volume of blood per heart beat. Yet, despite adopting different strategies, the Andean species and the bar-headed geese all managed to keep their blood equally well charged with oxygen, even at the lowest oxygen levels.

Lague says that the birds, 'appear to have evolved two strikingly different strategies for coping with low oxygen', adding that the discovery was a huge surprise to everyone involved. The bar-headed geese have evolved a flexible strategy where they breathe harder and their heart rate increases to provide sufficient oxygen during their high altitude migration. In contrast, the crested ducks and Andean geese, which spend their entire lives at altitudes in excess of 4000 m, have modified the surface of their lungs to allow them to pick up more oxygen without breathing harder. And when Lague and her colleagues compared the strategies of the high-altitude birds with those of the local high-altitude human populations that were already known, they were intrigued to see similarities in the responses: the Tibetan humans breathed harder, like the bar-headed geese, and the Andean humans breathed less hard, like the Andean geese and crested ducks.

However, she points out that not all of the strategies that have been adopted by humans that live at high altitudes are beneficial. 'Overproduction of red blood cells in high-altitude residents makes the blood thicker, which places increased strain on the heart and can lead to heart failure', she explains, but the birds have not fallen foul of the same problem.

10.1242/jeb.172361

Lague, S. L., Chua, B., Alza, L., Scott, G. R., Frappell, P. B., Zhong, Y., Farrell, A. P., McCracken, K. G., Wang, Y. and Milsom, W. K. (2017). Divergent respiratory and cardiovascular responses to hypoxia in bar-headed geese and Andean birds. *J. Exp. Biol.* **220**, 4186-4194.

Kathryn Knight

Individual variation matters for mussels

Mussels being monitored on the Central California coast. Photo credit: Lani Gleason.

As the tide goes out, every mussel clinging to the shore clamps its shell closed in preparation for the rise in temperature as the sun begins beating down. But the conditions encountered by each individual can vary dramatically, even between neighbours hanging onto the same rock. 'Individuals that are just centimetres apart can experience temperatures that are more different than individuals separated by hundreds of kilometres in latitude', says Lani Gleason, from California State University, Sacramento, USA. But what impact might environmental variations within a matter of centimetres have on the animals that experience them directly? Knowing that the temperature that ectothermic (cold blooded) animals experienced in the recent past can radically alter their physiology, Gleason's colleagues, Wesley Dowd, from Washington State University, USA, and Luke Miller, from San Jose State University, USA, decided to compare the responses of mussels

Inside JEB highlights the key developments in Journal of Experimental Biology. Written by science journalists, the short reports give the inside view of the science in JEB.

perched high up on the shore with those of animals that are rarely exposed to the air to find out how much their reactions differ.

After collecting mussels from the shore just beneath the Hopkins Marine Station, USA, Dowd and Miller allowed the animals to anchor themselves to individual acrylic plates. They then connected 30 individuals to a specialised circuit board to record each mussel's body temperature while also recording when they opened their shells to breathe and feed, before bolting the plates to the rocks at three different locations on the shore: just above the low tide line, in a tide pool and near the high tide line. 'We knew that the ocean would eventually destroy just about anything we put in it', laughs Dowd, who recalls getting up at 03:00, 03:30 and 04:00 h to maintain and service the monitors when they were exposed at low tide.

After 23 days, Dowd and Miller retrieved the battered equipment and the mussels to which they were attached to discover that the molluscs perched at the highest location on the shore suffered the widest range of body temperatures, differing by up to 14°C. And when the duo compared how long the mussels' shells were open to breathe and feed, it varied between 45 and 70% in the two positions lower down the shore. 'We were quite surprised at how much neighbouring mussels at the same tidal height varied in the amount of time they spent gaping [opening their shells] each day', says Gleason. And when she investigated the physiological impact on each mollusc of its individual microclimate, it was clear that the mussels that got hotter suffered more DNA damage and produced more of the antioxidant catalase to counteract the damaging effects of oxygen at the higher temperatures. Meanwhile, Jacob Winnikoff, George Somero, Paul Yancey and Dylan Bratz discovered that the hottest mussels produced more of the stabilising molecule taurine – which is known to protect animals from high temperatures – even when they were adjacent to cooler mussels on the same acrylic plate. Explaining that these strong correlations were even more impressive because the mussels were in the real world, instead of being cosseted in the lab, Dowd adds, 'This suggests that the underlying physiological mechanisms are pretty robust'.

So, mussels that are nestled up against each other have dramatically different experiences of the environment surrounding them: 'Individual variation matters', says Gleason. And this could have significant implications for how populations cope as temperatures continue rising. 'We think that this additional level of complexity in the way the environment varies and in the way that individuals respond to that variation further complicates the prediction of climate change effects', cautions Dowd.

10.1242/jeb.172387

Gleason, L. U., Miller, L. P., Winnikoff, J. R., Somero, G. N., Yancey, P. H., Bratz, D. and Dowd, W. W. (2017). Thermal history and gape of individual *Mytilus californianus* correlate with oxidative damage and thermoprotective osmolytes. *J. Exp. Biol.* **220**, 4292-4304.

Kathryn Knight

Xenopus larvae swivel reflex depends on contrast

One-month-old *Xenopus* tadpoles. Photo credit: Sara Hänzi and Hans Straka, http://bit.ly/2xKy2x2.

Some photographers take advantage of the blurring effect produced when animals and humans move past the lens at high speed to produce extraordinary images, but if animals didn't have a sophisticated system – the optokinetic reflex – to stabilise their vision while mobile, this smeary perspective would be our permanent reality. Céline Gravot, from the Ludwig-Maximilians-Universität München, Germany, explains that most animals swivel their eyes in their heads to counteract the effects of motion: 'You can experience this reflex when looking out of the window of a moving train; your eyes will move to follow the movement of the scene outside', she says. But Gravot and her colleagues Alexander Knorr, Stefan Glasauer and Hans Straka were curious to find out how the swivelling motion of the eye responds to specific features of a scene. For example, would the reflex movement respond in the same way to dark objects – such as a flock of birds or squadron of planes – silhouetted against bright daylight as it does to brilliant stars against a dark sky? As the vision of most mammals is too sophisticated to begin unravelling the answer to this question, the team focused on a simpler animal, the African clawed frog (*Xenopus laevis*) tadpole, which swivels its eyes to counteract the effect of its swimming motion. Designing a series of simple scenes – ranging from white dots on a black background, through various shades of grey, to black dots on a white background, in addition to crescent-shaped dots and small blocks – Gravot and Knorr swivelled the scenes before the eyes of stationary tadpoles while they filmed the animals' eye motions and recorded the electrical signals produced by the tadpoles' retinas.

However, the team was surprised when they realised that the tadpoles responded more strongly to the bright dots on the dark background than they did to the dark dots on a white background, swivelling their eyes through a wider angle in response to the white dots than the dark dots. In addition, the strength of the electrical signals generated by the retina also declined as the background became lighter and the dots darker. 'We did not expect that', says Gravot, as the only difference between the two scenes was the intensity of the spots relative to the background. The retina responded differently to both scenarios, ultimately altering the strength of the tadpoles swivelling reflex response.

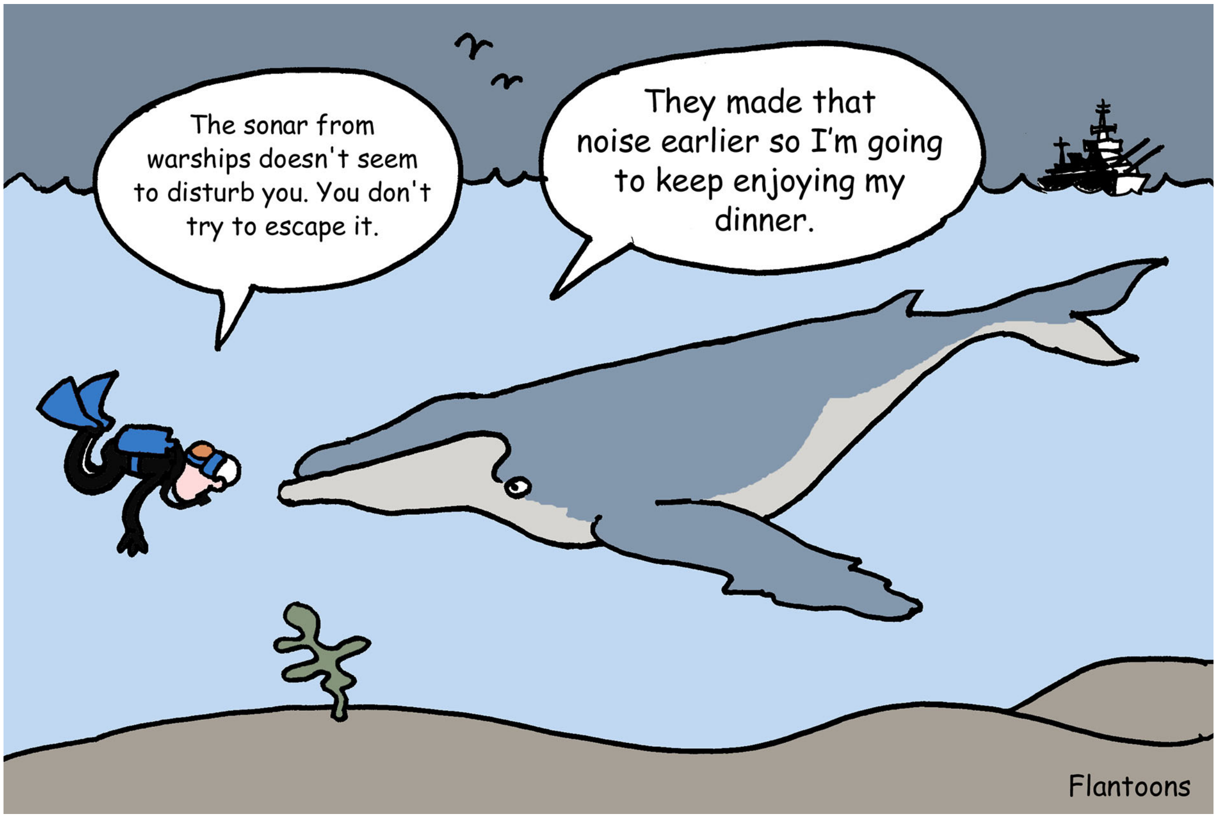
'This confirms again that the eye is a pretty smart sensory organ on its own', says Gravot, who suggests that the eye may be making a rudimentary interpretation of the motion of a scene to produce the reflex. And she also suspects that the tadpoles responded less strongly to the motion of dark objects because they could be interpreted as food particles, where as bright objects moving against a dark background could be the result of visual motion generated by the tadpoles' own movements, triggering a strong visual reflex in the animals. Gravot and her colleagues are now keen to discover how the tadpoles' drastic lifestyle change, when they metamorphose from aquatic larvae to amphibious hunters, affects their visual processing.

10.1242/jeb.172353

Gravot, C. M., Knorr, A. G., Glasauer, S. and Straka, H. (2017). It's not all black and white: visual scene parameters influence optokinetic reflex performance in *Xenopus laevis* tadpoles. *J. Exp. Biol.* **220**, 4213-4224.

Kathryn Knight

Humpback whales don't always avoid sonar



It is becoming increasingly difficult for whales and other mammals that echolocate and communicate by singing in the oceans to be heard above the volume of man-made noise. And many scientists are also concerned that our noisy activities in the oceans could be damaging the hearing of these sensitive creatures. However, Paul Wensveen, from the University of Iceland, and an international team of collaborators explains that many navies that depend on sonar for detection have developed a strategy where they gradually increase sonar volume, in the hope that the animals will move away calmly before the sound reaches full volume. But no one knew how effective these warning strategies were until Wensveen and his colleagues recorded the responses of 13 humpback whales to sonar in the Barents Sea north of Norway.

After attaching data logging tags – which recorded sound and movement – with suction cups to individual whales, the team then sailed toward the animals towing a sonar emitter and recorded the animals' responses as they gradually increased the sonar to full volume. Wensveen says, 'The risk of inducing hearing loss with an intense sound source like naval sonar depends on both the peak pressure and the sound energy received by the animal', so he and his colleagues measured the pressure of the sound waves reaching the whales and the amount of sound that the animals were exposed to, in addition to their distance from the sonar, to estimate the risk to the animals' hearing.

While five of the 11 animals veered away from the ship on the first occasion, the team found that the animals' evasive action did reduce the chances of them encountering damaging levels of sound. However, the animals that had responded when the sonar first sailed toward them were more reluctant to veer away on the second occasion; only a mother and her calf avoided the increasing noise, although three animals that had been undisturbed by the first pass took evasive action on the second occasion. The team suggests that humpback whales may be reluctant to avoid sonar if they have heard it before or are distracted by food, and they suspect that the strategy of gradually increasing the volume may be more effective with other species that are more sensitive to sonar disruption.

10.1242/jeb.172379

Wensveen, P. J., Kvadsheim, P. H., Lam, F.-P. A., von Benda-Beckmann, A. M., Sivle, L. D., Visser, F., Curé, C., Tyack P. L. and Miller, P. J. O. (2017). Lack of behavioural responses of humpback whales (*Megaptera novaeangliae*) indicate limited effectiveness of sonar mitigation. *J. Exp. Biol.* **220**, 4150-4161.

Kathryn Knight
kathryn.knight@biologists.com

Journal of Experimental Biology