INSIDE JEB

Superparasitism is a price worth paying for parasitic wasps

Two female *Eupelmus vuilleti* perched on a black-eyed pea. Photo credit: Sonia Dourlot.

Finding a good nursery for the kids is a dilemma that many new parents can relate to and parasitic wasps are no different. Competition between wasp mums can be keen when the species that will host their offspring can support only one wasp larva at a time. Add to that the sheer effort that a soon-to-be mum must invest to drill through the tough exterior of a fruit or seed to access the host larva within, and parasitic wasp mothers might have to invest significant amounts of energy to ensure that their offspring get the best start in life. Wondering how much importance pregnant wasp females place on these costs when staking a claim to a host larva, Romain Boisseau and Marlène Goubault from the Université François-Rabelais, France, and Art Woods from the University of Montana, USA, measured the amount of energy expended by female *Eupelmus vuilleti* parasitic wasps as they duel over and then bore through a black-eyed pea in search of weevil (*Callosobruchus maculatus*) larvae within.

'Females that start drilling a seed kick and chase intruders until the loser retreats', explains Boisseau, who recorded the amount of carbon dioxide exhaled by duelling *E. vuilleti* females as they grappled over a weevil-infested black-eyed pea to find out how costly the exertions were. However, the main technical challenge was finding a way to directly measure the carbon dioxide produced by the duelling wasps while the weevil larva inside the pea continued exhaling carbon dioxide. Fortunately, the team discovered that the wasps were content to lay their eggs on weevils that had just died, so Boisseau provided the sparring females with recently frozen black-eyed peas containing a dead weevil to battle over. Yet, when he compared the amount of carbon dioxide produced by the females during combat with the amount of carbon dioxide that they produced when there was no weevil larva to squabble over, the total daily cost was a measly 0.001%, in contrast to the massive energy costs incurred by other species during combat.

In contrast, when Boisseau recorded the amount of carbon dioxide exhaled by individual females as they bored through the tough seed in search of the weevil larva and calculated the total amount of energy that they expend drilling over the course of a day (16 holes on average), he was amazed that the exertion used as much as 15% of the wasp's energy budget. However, when Boisseau offered the wasps a seed that had already been drilled by a previous visitor (who had already laid her egg within), he was impressed to see that the late arrival saved time (using only 12% of the time it took to drill into a fresh pea). In total, a female could save up to 6% of her daily energy budget, despite the risk that her larva has a lower chance of surviving on a weevil that has already been parasitised – superparasitised – by another wasp mum.

Although superparasitism might not seem like a great idea when it reduces a larva's chance of survival, Boisseau, Goubault and Woods suspect that the energy and time saved using a second-hand hole may partly outweigh the risk that the larva won't make it. They also add that reusing a drilled hole could help to avoid wear and tear at the tip of the wasp's egg-laying microinjector. And the trio suggests that the sheer exertion of egg laying could also account for the wasps' lacklustre combat performance; 'There may be little benefit to fighting fiercely to access an unparasitised host', they suggest.

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Boisseau, R. P., Woods, H. A. and Goubault, M. (2017). The metabolic costs of fighting and host exploitation in a seed-drilling parasitic wasp. *J. Exp. Biol.* **220**, 3955-3966.

Kathryn Knight

King crabs can't cope below 1250 m

Lithodes maja, a member of the king crab family. Photo credit: Alastair Brown.

Unless you step into an elevator that whisks you to the top of one of the planet's tallest buildings, it can be hard to appreciate the pressures that we are normally under. Most terrestrial species spend the majority of their lives oblivious to the 1 kg of air pressing down upon each square centimetre at sea level. But pressure is a pre-eminent factor in the survival of many marine species. Alastair Brown from the University of Southampton, UK, explains that little is known about the impact of high pressure on the physiology of many of the species that make their homes at depth. He says, 'There appears to be a physiological bottleneck imposed on shallow-water creatures by decreasing temperature and increasing pressure between 1000 and 3000 m deep', adding that few stray deeper. But there was little evidence for how increasing pressure might compromise survival.

With an entire ocean of species to choose from, Brown and Sven Thatje decided to focus on one member of the king crab family, *Lithodes maja*, which is content at depths ranging from 4 to 790 m around the northern European coast and North America. 'The crabs' latitudinal range in shallow water appears to be limited by

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the physiological impacts of temperature: too cold towards the Arctic and too warm towards the Tropics', says Brown; but it wasn't clear why the crabs could go no deeper. After driving crabs, which had been collected by Bengt Lundve and Tony Roysson, 1800 km from Sweden to the National Oceanography Centre Southampton, Brown fitted heart rate monitors to the crustaceans' shells and then installed the animals in high-pressure vessels before gradually increasing the pressure in 2.5 MPa steps (the equivalent of dropping them down 250 m) to 20 MPa – corresponding to a depth of 2000 m.

Monitoring the animals, Brown saw their heart rate fall from about 35 beats min^{-1} at the shallowest water pressures to ~17 beats min^{-1} at the highest pressure. And when he analysed the crabs' oxygen consumption, he was amazed to see it increase gradually up to a pressure of 12.5 MPa – the equivalent of a depth of 1250 m – before crashing dramatically as the pressure continued rising. 'The decrease in metabolic rate [oxygen consumption] at high pressures greater than 12.5 MPa likely represents a distinct physiological response indicating extreme stress', says Brown.

And when James Morris and Chris Hauton investigated how the crabs' bodies responded to the stress, they saw evidence that the crustacean's nervous system might be impaired at high pressure while the animals also produced proteins that are designed to protect the body from the effects of stress. However, Andrew Oliphant, David Pond and Elizabeth Morgan found no sign that the animals altered the structure of their cell membranes (in order to maintain function at higher pressures) or switched to anaerobic respiration before their oxygen consumption dwindled.

Explaining that the metabolic cost of coping with high pressure probably accounts for the crabs' distribution, Brown says, 'We think that *L. maja*'s pressure tolerance is limited by the effects of high pressure on neurotransmission, which interferes with heart function and thus limits the ability to supply sufficient oxygen to cells to meet the elevated metabolic demand at high pressure'. And he urges scientists that are concerned about the impact of climate change on marine species to add pressure to the list of factors that they consider when attempting to predict population shifts. 'Such an approach is crucial for accurately projecting biogeographic responses to changing climate', he warns.

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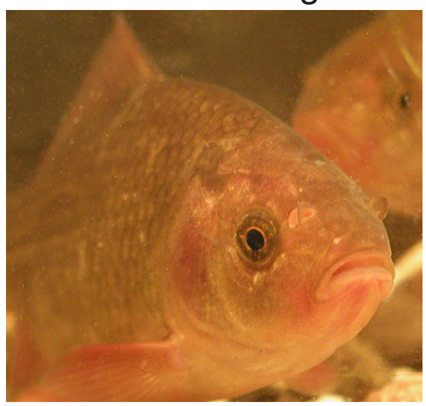
Kathryn Knight

Crucian carp recover from winter brain damage



Crucian carp. Photo credit: Goran Nilsson.

At first glance, elegant crucian carp and freshwater turtles may appear to be strange bedfellows, but they share a remarkable superpower. Both animals are capable of surviving for months without oxygen, emerging apparently unscathed from icy lakes and puddles at the end of winter when the sun returns. But Sjannie Lefevre and colleagues from the University of Oslo, Norway, and the University of West Scotland, UK, weren't so sure; could the remarkably robust fish be suffering brain damage as a result of oxygen deprivation and the subsequent return of oxygen?

Intrigued by the possibility, Lefevre and colleagues went fishing in a small lake near Oslo to collect carp before exposing them to a mini-winter followed by spring in the lab by supplying them with deoxygenated water for 1 week before turning the air back on for a day. Checking for signs of cell death in the fish's brains, the team was impressed to see that the cell death rate was unaffected while no oxygen was available. However, as soon as the oxygen returned, the brain cell death rate more than doubled. And when the team checked to find out how the cells were dying, there was no evidence of the programmed form of cell death (known as apoptosis) that naturally tidies away defunct cells, suggesting that the brain cells might be dying through other, more destructive or unconventional processes. However, when the team tested for signs of cell growth 1 day after the oxygen returned, neither the fish in the oxygen-rich water nor those in the oxygen-poor water seemed to be rebuilding their brains, although Lefevre points out that recovery may occur later.

As the oxygen levels in lakes vary naturally over the seasons, the team collected fish when the lake oxygen levels were highest in summer and early autumn, and at their lowest in late autumn and winter, and checked for signs of brain cell death. Interestingly, the winter fish showed relatively low levels of brain cell death by apoptosis; however, the summer and early autumn fish were disposing of brain cells at a higher rate.

Having discovered that the fish experience serious levels of brain damage through cell death when the oxygen returns in spring, the team tested how the damage affected the fish's memory. After training small groups of the fish to navigate a maze in return for a food reward, the team plunged the fish into a brief simulated winter followed by a day of spring. Despite experiencing brain damage following the return of oxygen, the fish were able to reach the food reward at the end of the maze as fast as they had before the simulated winter; however, their memories were poor and they took more wrong turns. But when the scientists tested the ability of the brain-damaged fish to learn how to navigate the maze, they found that the animals picked up the task quickly: 'They were able to repair any brain damage caused by anoxia/re-oxygenation', says Lefevre.

So, crucian carp suffer brain damage when oxygen floods back into their systems at the start of spring, and memories formed before the winter suffer, but they seem to regain the ability to learn after repairing the damage. However, Lefevre points out that the same may not be true for turtles. 'They utilise markedly different strategies to survive without oxygen', she says, pointing out that the turtles are virtually

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comatose and inactive when their oxygen supply is cut off, while the carp remain active, probably leaving the fish more vulnerable to damage when the oxygen returns.

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Kathryn Knight

Did we inherit silicosis from our ancient ancestors?

Not all dusts are equal. While many are benign, some are potentially lethal and the ill effects of inhaling coal and silica dust from rock may only become apparent when victims develop silicosis after years of exposure. However, Marina Pozzolini and colleagues from the University of Genova and the Polytechnic University of Marche, Italy, explain that some sponges actively engulf silica crystals into their bodies in much the same way that damaging dust particles are encased in the lungs of silicosis sufferers. Intrigued by the possibility that modern humans may have inherited the debilitating industrial disease from our ancient sponge ancestors, Pozzolini and her colleagues began investigating how *Chondrosia reniformis* sponges react when they incorporate minute silica crystals into their bodies.

Sure enough, when the team exposed the sponges to silica dust, they appeared to show many of the same symptoms as human silicosis sufferers, producing fibres of collagen and a protein (tumour necrosis factor) that causes inflammation in the lungs of humans. However, the sponges' response did not appear to be counter-productive. In fact, the beneficial symbiotic bacteria that colonise the sponges flourished after the simple animals engulfed the dust and the team also realised that the sponges were able to incorporate the silica into their skeletons for strength.

'This phenomenon seems to indicate that quartz engulfment and erosion in *C. reniformis* is a positive event for the physiology of this sponge', the team says, adding that the knowledge that factors (tumour necrosis factor) that cause inflammation in human silicosis sufferers appear to have persisted over the aeons may help scientists to develop better remedies for modern-day victims of silicosis.

10.1242/jeb.172072

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