trying to find out whether insects breathe discontinuously to protect themselves from dehydration or the harmful effects of oxygen. 'A number of papers have attempted to examine the issue of water balance by looking at desert insects. The argument was that insects from a dry environment should show an exaggerated discontinuous breathing pattern because they have to conserve water in such an extreme manner. But, the results have been mixed,' explains Bradley. So, he and Heidy Contreras decided to look at the problem from a different perspective. They monitored the breathing patterns of waterstriders that live in humid environments to find out whether they use a discontinuous breathing pattern (p. 1086). 'One simple hypothesis would be that they shouldn't use discontinuous breathing at all because they don't face the problem of dehydration,' says Bradley.

Collecting waterstriders from a mountain stream and bringing them back to the laboratory, Bradley and Contreras recorded the insect's breathing patterns in dry and humid conditions and at three different temperatures (to vary the insects' metabolic rates and oxygen demands) by measuring the amount of carbon dioxide exhaled. In humid conditions, the duo saw that the insects with high metabolic rates at 30°C breathed continuously to meet their metabolic demands. However, the insects with the lowest metabolic rates (at 10°C) breathed discontinuously. Even though the atmosphere was humid enough to protect the insects from dehydration, they still breathed discontinuously.

The duo also compared the breathing patterns of waterstriders with the same metabolic rates (at 20°C) in humid and dry environments and found that they were identical. The insects' breathing patterns would have been different if they were regulating them to conserve water, so the insects were not modifying their breathing patterns to protect themselves from dehydration. They must be regulating their breathing patterns to prevent oxidation damage when their metabolic rates are low.

Bradley explains that the insect respiratory system is so efficient at delivering oxygen that it can open for just a minute when the insect's oxygen demands are low and saturate the body with oxygen. Then the spiracles have to close as the insect consumes oxygen, returning it to a safe level. Instead of detecting humidity to protect the insect from dehydration, the insect's respiratory system detects oxygen and carbon dioxide levels and closes when oxygen levels are dangerously high.

'I would hope that this paper puts an end to the notion that the insect is monitoring water vapour and changing its respiratory behaviour,' says Bradley. He adds, 'We understand the whole animal pattern of respiration but what we are now trying to do is to understand what is going on at the level of the spiracles: when do they open and close, how far do they open, what nerves control that, where is the location of the oxygen sensor and the carbon dioxide sensor; but those are tough questions to answer.'

10.1242/jeb.057281

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DARTERS SIT TIGHT IN BOUNDARY LAYER


Rose Carlson

Sitting comfortably on a riverbed might seem to be an easygoing lifestyle, but you try doing it in a fast running stream. Yet tiny North American darters appear to be perfectly at home holding still in fast flowing water, apparently without gripping on. Rose Carlson from Fordham University, USA, explains that she is fascinated by how animals' body shapes evolve. She says, 'I was interested in whether darters' body and fin shape might contribute to their ability to stay on the bottom.' She explains that environmental factors often drive an animal's evolution, so she and George Lauder from Harvard University decided to find out more about the turbulent fluid flows the fish frequent (p. 1181).

'This project started out being very exploratory. We just wanted to describe the patterns of flow over different substrates,' says Carlson. Placing simulated riverbeds in a flow tank and shining a plane of laser light in the water as it flowed at speeds ranging from 0 to 31 $cm\,s^{-1}$, Carlson and Lauder were able to visualise the turbulent flows as the water rushed over the surfaces. Comparing the flows over the gravelly river beds with the flow over a smooth Plexiglas surface, Carlson and Lauder were surprised to see that water close to the gravel flowed much slower than water in the main body of the 'river'. This region of relatively tranquil water above the Plexiglas increased from a few millimetres to almost 2 cm as the water tumbled over the gravelly riverbeds. And when the duo introduced a large rock into the flow, the water behind the obstruction even began flowing backward slightly. Friction between the water and the coarse surface was slowing the flow near the riverbed significantly to produce a tranquil boundary layer, but how could this help the darters?

Carlson realised that the fish were almost the same height as the newly discovered region of reduced flow. This layer of slower flowing water was deep enough to shelter the fish and help them sit tight, but the fish must be modifying the fluid flows in some other way to help them stay put. Working with Lauder, Carlson began visualising the fluid flows around the darters' pectoral fins as the fish held them out wide while they sat still on a simulated riverbed and a Perspex surface.

According to Carlson, some fish, such as sharks, produce downward directed forces with their pectoral fins; however, when she and Lauder analysed the flow patterns trailing from the darters' widespread fins, they were surprised to see that they were not producing enough force to pin the fish to the bottom, even in the slow flowing water. 'They are probably using some other mechanism to generate a lot of friction between themselves and the substrate, and those frictional forces are probably the important force helping them to stay in place,' she says.

Having found that darters take advantage of slow flowing water in the boundary layer to remain in place, Carlson is curious to find out more about how this could have shaped the explosion of darter species in North America. She explains that there are over 240 species and says, 'There is an important phenomenon that often precedes adaptive radiation [when new and ecologically diverse species appear], which is the availability of unoccupied ecological space.' Carlson would like to find out whether the darters' reduction in size and loss of a swim bladder allowed them to occupy the tranquil – and under-used – boundary layer, giving them the 'ecological opportunity' to diversify into the wide range of species we see today.

10.1242/jeb.057307

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