of their time digging and fighting over unmated females on the hot ground, while the smaller males hover near vegetation, watching for females that may have escaped the affray below. Even in the shade, desert air temperatures are hot, so how do the larger male bees tolerate the sizzling temperatures in direct sunlight? Meghan Barrett and Sean O'Donnell at Drexel University, USA, believe that lighter-coloured males can stay on the hotter ground longer without overheating in part because their pale hairs can reflect more sunlight.

After collecting large and small male bees from the desert in Arizona, USA, Barrett and O'Donnell brought them to the University of Illinois, USA, to measure just how much light reflects off the bees' bodies. They found that the pale backs of large males were more reflective than those of the smaller, dark bees. Reflecting more light means that larger male digger bees heat up slower in direct sunlight and can withstand the scorching sun better than their darker, smaller counterparts. However, the researchers still didn't know what the light was reflecting off – was it the hairs on their body or their hard exoskeleton?

To answer this question, they measured the amount of light reflecting off the bees after shaving the hairs from the insects' backs. They found that removing the hairs from both the large and small males decreased their ability to reflect sunlight. But, having paler hairs enables larger male digger bees to stay cooler on the hot ground, where they can get first access to unmated females emerging from their underground burrows. So why might smaller males have darker hairs, if being a paler colour would better help them avoid overheating? The darker hairs of the smaller males could allow them to warm up quicker by absorbing more sunlight, so they can fly and find females earlier in the cooler mornings than larger males.

Generally, researchers make predictions about how climatic warming will affect a given species. However, Barrett and O'Donnell suggest that we need to consider that not all members of the same species will respond in the same way. For example, as climate change threatens animals with warmer and more variable temperatures, large male digger bees may have an advantage when competing for mates on hotter days. Yet, small males may benefit on cooler days by having a colouration that allows them to fly earlier by absorbing more heat. The need to focus on understanding the behaviour and abilities of individual organisms is paramount, especially if we are to predict how they will fare in a changing world.

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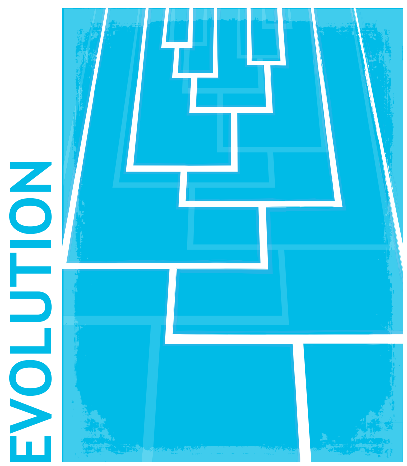
## Mudskipper movies link blinking with life on land




We don't tend to think about what it means to blink. This simple act, which is so common among terrestrial animals, occurs in many diverse ways. Ducks, for instance, blink by raising their lower eyelids, while mongooses often utilize a thin membrane, sometimes referred to as a third eyelid, which passes across the eye from the head towards the tail. Aquatic animals, however, largely lack the ability to blink. This led a multidisciplinary team from the USA and Australia, headed by Brett Aiello, to hypothesize that blinking may have arisen when animals transitioned from water to land. To investigate why blinking first evolved, the team examined mudskippers, amphibious fish that spend most of their time on land. Perhaps not so coincidentally, they also belong to the minority of aquatic animals that blink. Aiello and colleagues began by analysing how mudskippers blink their eyes before delving into why.

From watching movies of Indian mudskippers (*Periophthalmus barbarous*) and African mudskippers (*Periophthalmodon septemradiatus*) blinking on land, the team discovered that these land-frequenting fish blink by lowering most of their eye into a cavity in their heads and raising a membrane to cover the rest of it, which is notably different from blinking in ducks and mongooses. How long mudskippers blink for, however, was comparable to spontaneous blinks in humans. When the researchers compared the eye muscles of mudskippers with those of a non-blinking fully aquatic fish, they found no notable differences. This suggested that the mudskippers must be using an existing set of muscles to blink. Likewise, Aiello and colleagues didn't find any tear glands in mudskippers, but they did discover cells on the head that produce mucus that would spread around, wetting the mudskipper's eyes when blinking. So, blinking may serve to wet the eye in mudskippers as it does in land-dwelling animals.

Next, the group turned their attention to discovering why mudskippers blink. To test whether blinking indeed serves to wet the eye, they filmed mudskippers under simulated windy conditions using fans. The windy conditions caused 30 times more evaporation than normal, which made the mudskippers blink more. Moreover, the researchers noticed that dehydrated mudskippers more often rolled their bodies on the damp tank floor, a behavior which captures water to wet the eye. Together, these observations indicate that mudskippers blink and roll to moisten the eye while on land.

Preventing the eye from drying out isn't the only reason that animals blink their eyes. To consider whether blinking also cleans debris from the surface of the mudskipper's eyes, the researchers dusted the eyes with dried brine shrimp eggs. The mudskippers removed ~97% of the dusty substance from their eyes after just one blink. To test whether blinking provides protection from bumps, the researchers lightly tapped the eye surface with a cotton swab, causing the fish to blink. This reflexive blink usually happened within 30 ms and lasted about twice as long as a spontaneous blink. Based on this, Aiello and colleagues suggest that blinking serves an additional function in these fish – to protect the eye from impact injury by encroaching objects. Thus, mudskippers blink for at least three reasons and these shared experiences might explain why this complex behavior occurs in a fish that is so distantly related to animals that live in the air. Although we remain largely unaware of our eye blinking in everyday situations, the behavior serves several functions, each tied to the challenges of leaving life in the water behind.

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# Ocean acidification causes some fishy side effects


The ocean picks up our slack when it comes to climate change by absorbing a substantial amount of the carbon dioxide we produce. While this helps to mitigate global warming, it also increases the acidity of seawater in a process called ocean acidification. Unsurprisingly, there is global concern over the impact of ocean acidification on marine life, but understanding the extent of its effects is an active and somewhat contentious area of research. One of the main controversies centers on whether ocean acidification affects fish behavior. Trevor Hamilton from MacEwan University and Alberta University, Canada, and Martin Tresguerres from the University of California, San Diego, USA, worked with an international group of colleagues to examine the impact of current and predicted changes in ocean acidity on the behavior of bicolor damselfish (*Stegastes partitus*) in Panama.

The team started by holding damselfish in seawater, either at current ocean acid levels or at those predicted with climate change, for 5 days. Then, they videoed the fish's response when placing them in four testing arenas that assessed their movement, boldness, aggression and anxiety. While most behaviors were not affected by ocean acidification, anxiety was higher in the acidic seawater than in the current-day seawater.

After establishing that the damselfish's behavior was impacted by ocean acidification, the team wanted to figure out how it happened. They hypothesized that increases in ocean acidity affect the dopamine response in the brain. Changes in this neurotransmitter can influence animal movement, boldness and more, which would explain why the fish behaved differently in the more acidic seawater. To test this, they exposed the fish to a drug that mimics dopamine and ran the same behavioral tests on them. The team discovered that the dopamine mimic affected the fish in current-day seawater – the animals moved less and they were bolder and more anxious – but the behavior of the fish in acidic water did not change. This confirmed the team's suspicion that ocean acidification disrupts dopamine signaling to impact fish behavior.

But, as the researchers ran their experiment, they noticed something odd. While their fish tanks were constantly supplied with fresh seawater, the tank water grew more acidic throughout the study, likely because of the fish's own carbon dioxide production. As damselfish spend much of their time in small coral reef crevices where water mixing is minimal, the team wondered how acidic the seawater was in the fish's natural habitat and how it compared to the global-scale future predictions that had informed their study design. They collected water samples from the crevices where the damselfish live and outside in the open reef. Surprisingly, seawater from the damselfish crevices was acidic, like the climate change scenario used in the study, while the surrounding reef seawater was similar to normal current conditions. Importantly, these acidic readings were not caused by climate change; they are just a natural phenomenon in the reefs.

These findings demonstrate that there is no universal 'normal' or 'climate change scenario' that can be applied to an entire ecosystem. Instead, there are smaller microhabitats within an ecosystem that may differ in their environmental conditions. With this new information in hand, the researchers speculated that the increased anxiety they observed in damselfish exposed to acidic water may help the fish seek shelter in crevices to avoid being eaten by bigger fish. One has to wonder whether these tiny fish have figured out a way to use acidic water to their advantage and what other treasures of information we can unlock if we follow up our experimental observations and always consider the ecology of the animals we study.

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