OUTSIDE JEB

For salty toads, timing is everything

Rising sea levels, drought and land-use change increase salt levels in freshwater coastal environments. Maintaining an optimal amount of salt in the body is crucial for animals but incredibly hard to do, particularly for those adapted to low-salt freshwater environments that suddenly face a rapid salt increase. Because of their highly sensitive skin, toads, which reproduce and develop in fresh water, are often especially vulnerable to salty water. Léa Lorrain-Soligon, from the Centre d'Etudes Biologiques de Chizé, France, collaborated with colleagues from the same institution and Ligue pour la Protection des Oiseaux, France, to investigate the impacts of salty water on coastal toads (*Bufo spinosus*) across multiple life stages, from egg laying through to early tadpole development.

It takes a lot of energy to survive in salty water, even for animals that are used to it, so the scientists wondered whether dealing with extra salt would drain the toads' energy, leaving less available to reproduce. To explore this, the team captured breeding pairs of male and female toads and set them up in tanks containing high or low (freshwater) amounts of salt. Then, they measured the size and number of eggs the toads laid in the two water conditions. While the toads laid the same number of eggs regardless of the water type, those in saltier water ended up with much smaller eggs, indicating that the higher energy costs of dealing with the salt had, indeed, led to lower-quality eggs.

Next, the team wanted to know whether the larger size of the eggs laid in fresh water would translate into healthier, more robust tadpoles. They split the two batches of eggs (laid in salty or fresh water) into four groups: half were kept in the same water, and half were moved to the opposite water type. Not surprisingly, eggs left in salty water struggled. But there was a catch: several eggs that were moved from salty to fresh water were healthier and the tadpoles grew better after hatching. Interestingly, the opposite could not be said for the eggs laid in fresh water, then placed in salty water before hatching. Those tadpoles were much smaller and more likely to hatch with deformities than any other group. These results demonstrated that exposure to salt is tough on reproducing toads. Still, if the toads can find a way to lay their eggs in fresh water, the offspring have a high chance of surviving.

Once the eggs had hatched, the researchers took the young tadpoles and, once again, split them into salty or fresh water, leading to eight different groups that had experienced various combinations of fresh and salty water throughout development. The scientists measured how well the tadpoles grew under the different combinations of fresh and salt water exposure and found that the tadpoles kept in fresh water their entire lives were the best off – they grew fastest and were bigger than those grown in salty water. Interestingly, tadpoles that experienced salt early on but were subsequently raised in fresh water were almost able to catch up to the larger size of the freshwater-only group, presumably by boosting their growth rate to compensate for their smaller size.

These findings underscore the significant challenge salt poses to toads, particularly during critical early life stages. The study's unique and intricate design uncovered something remarkable: tadpoles could partially rebound from early salt exposure when placed back in fresh water. Clearly, the timing of salt exposure is a key factor impacting toad survival rates across life stages. Results like these help us identify when, where and how salt affects vulnerable animals, which, in turn, tells us when to intervene to help them.

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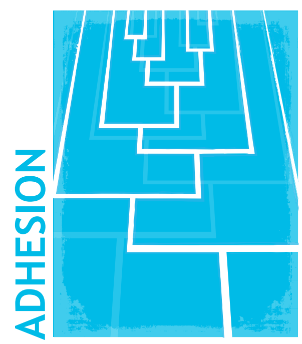
Sticky spittlebug foam forms predator pitfalls



Spittlebugs are a group of insects lovingly named for the sticky foam that they leave on plants. These insects attach to a host plant and feed on the sap that moves through the plant tissue. The sap passes through the spittlebug's digestive system and is excreted from the anus as a clear, sticky fluid that the spittlebug then breathes into, creating foam. The spittlebugs can produce 150–280 times their body mass in this fluid every day. The foam plays many important roles in the spittlebugs' lives, including keeping them moist, repelling predators through the unpleasant smell or touch, protecting them from the sun's heat and light, and acting as an antimicrobial to keep germs at

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bay. While some of these amazing properties of this foam are known, there is still much to discover. To better understand how the foam interacts with structures such as the host plant or predators, Hannelore Hoch from Museum für Naturkunde, Germany, and colleagues from Technische Universität Dresden, Entofilm, Germany, and Christian-Albrechts-Universität zu Kiel, Germany, decided to document how the foam interacts with surfaces and how some spittlebug predators may behave when dealing with the foam.

To uncover more about the foam, the researchers collected spittlebugs and predators, such as ants and spiders, from various grasslands and marshes in Berlin, Germany. They recorded how the spittlebugs produce the foam, whether the predators avoided the foam and how predators behaved when forced to interact with the foam. The researchers also measured the contact angle, evaporation and pull-off forces of the foam to study its physical properties.

The team discovered that although the spittlebugs were surrounded by the foam, they were still able to move about as normal; the foam did not hinder them. When they checked how predatory ants interacted with the foam, they discovered that the insects visited a droplet of foam placed on a glass dish as often as they did a droplet of water, which may suggest that the ants try to use the foam to satisfy their thirst. However, when the ants walked into the foam, they struggled to escape and had to groom vigorously to clean themselves after breaking free. The foam was also capable of spreading over various surfaces, including the water-repellent, hydrophobic, surfaces found on many plants. It also turns out that the foam evaporates faster than water, which likely explains why the spittlebugs have to produce so much. And, as the foam dries, it gets stickier, which probably makes it even more difficult for predators when they make physical contact with it.

Understanding more about the sticky substance that the spittlebugs produce can teach us a lot about the ecological interactions between the spittlebugs, the plants upon which they reside and the predators that feast on them. The physiological process of creating copious amounts of foam can protect the insect from predators and the harsh environment around them, while the unpleasant flavour is also likely to deter animals from eating the plants that they live on. Interestingly, the sticky wet foam could also inspire the next generation of medical adhesives. While the thought of this foamy excrement many not be particularly appetizing, spittlebug foam is remarkably versatile, providing shelter and safeguarding young spittlebugs as they grow and transition to the next phase of life.

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Fossil echoes: katydid hearing through the ages

Insects have ears in their legs that help them hear other insects and danger. Katydids, relatives of grasshoppers and crickets, were among the first insects to make sounds and they produce the broadest range of calls across the entire family range. Their ancestors were making and hearing sounds more than 200 million years ago, long before the family expanded dramatically during the Eocene era (56–34 million years ago). Present-day katydids hear sounds ranging from 600 Hz to 150 kHz, which is much broader than the hearing range of humans (0.02–20 kHz), and make sounds for mating and communication by rubbing parts of their wings against each other. But what did the most ancient katydid ancestor sound like and what frequency range was their hearing tuned to? To find out, Charlie Woodrow and Fernando Montealegre-Z from the University of Lincoln, UK, with Emine Celiker, from the University of Leicester, UK, decided to take a look at the wing and outer ear of an impeccably preserved fossil of the extinct katydid *Eomortoniellus handlirschi* embedded in amber, from the Natural History Museum, UK.

To understand the structure of the ear, the team used high-definition X-ray scans to examine the entire fossil, looking for structural details. The scans revealed a small opening in the outer ear that directed sound through a canal to the vibrating eardrum, called the tympanum. Both the ear canal and the tympanum, which likely vibrated in response to sound waves, were completely preserved. The team then focused on the external part of the ear, called the pinnae, which captures high-pitched sounds, to learn more about the frequency range of the ancient insect's hearing. They 3D printed a model of the pinnae, 30 times larger than the real ear, placed a microphone in the cavity at the centre and played sounds to the model, recording which frequencies, and how strongly, the model transmitted sound to the microphone. Rescaling their measurements down to the size of the ancient ear, the team discovered that *E. handlirschi* could have picked up sounds over 400 kHz, which is higher than the pitch of the echolocation calls used by bats for navigation.

Having figured out what the extinct katydids could hear, the team then measured the frequency range of the sounds they could have produced by measuring the teeth-like structure on the wing that the insects used to make sound. Based on the length of this structure, called the stridulatory file, and some mathematical calculations, the team estimated that the song was pitched around 32 kHz, in the ultrasound range. So, insects evolved the ability to communicate at this high pitch 56–34 million years ago.

The researchers also calculated how the ancient insect's ear canal vibrated in response to sound and how it amplified or dampened specific pitches before they reached the eardrums. The calculations indicated that the left and right ear canals naturally resonated at frequencies around 30.0 and 30.6 kHz respectively, which also matches the ultrasonic hearing range of modern katydids. In addition, the ears of *E. handlirschi* detected changes in sound pressure both internally and externally, allowing them to discern the direction of sound, similar to present-day katydids and crickets. The fact that sound moved more slowly through their ears (180 m s^{-1}, compared with 343 m s^{-1} in the open air) suggested a dependency on delayed internal cues to determine the sound direction. Unlike their living relatives, which use the ears on their legs to hear their kin and predators, the extinct *E. handlirschi* utilized their legs primarily for directional hearing.

This study by Woodrow and colleagues expands our understanding of katydid communication strategies across time. And, although the specimen that they investigated is preserved in amber, it is fascinating to think that the vestiges of this ancient katydid's communication system are preserved in every katydid alive today.

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Soaring at sea: migrating cranes surf weather fronts

Many of us have seen large flocks of birds such as geese flying overhead and wondered, where are they going? When migrating, many birds travel incredibly long distances. Birds use one of two strategies to make these journeys: flapping flight and thermal soaring. Thermal soaring involves riding rising air currents (thermals) up and then gliding down, meaning that the birds don't have to flap their wings, thus saving energy. When it comes to migratory birds, there are two distinct categories. Firstly, there are terrestrial migratory birds, such as cranes, and seabirds, such as gulls. Secondly, there are birds that only use thermal soaring while migrating and those that switch between flapping and soaring. It was thought that the thermals required for soaring fight were not available over the sea, so that birds either avoided travelling across water or resorted to flapping as they flew over. This was based on the observation that many migratory birds seem to avoid the ocean on their routes. However, a global team of researchers from Israel, the USA, Russia and South Africa recently showed that this is not the case for the common crane (*Grus grus*), suggesting that many birds may be able to take advantage of thermal soaring while crossing the sea.

Sasha Pekarsky and colleagues decided to monitor the migration strategies of the common crane, as they are the heaviest bird that uses both energy-saving soaring and expensive flapping flight during migration. To test their idea that birds may be able to use soaring flight when crossing the sea, the researchers fitted 44 common cranes in Western Russia with GPS dataloggers, which allowed them to determine each bird's location and altitude, and whether it was flapping or gliding at any individual moment. Between 2018 and 2021, the researchers collected over 1500 hours of observations during the cranes' migratory flights between western Russia and Africa, and back, crossing both land and sea (Black or Mediterranean) during the spring and autumn migrations.

Reviewing the measurements collected during the crane's lengthy flights, the team realised that the birds use a combination of thermal soaring and flapping flight over both land and sea. The amount of time that the cranes spent soaring varied depending on which region the birds were in, soaring on rising thermals most over the desert and least over the sea. The season also affected how much time the birds spent soaring on rising thermals, with the birds soaring more over the sea in the autumn. Additionally, the amount of energy saved when soaring was the same whether the birds were crossing over land or sea. The team also realised that the birds switched from flapping to soaring flight over the sea when they could ride thermal updrafts generated in the wake of a cold front following a low-pressure system passing over the water.

Considering the pressure systems that allow cranes to benefit from thermal soaring, it now looks as though the apparent lack of migration routes over the sea has more to do with fewer low-pressure systems, and cold fronts, crossing over seas rather than a complete lack of rising air currents, which are essential for energy saving thermal soaring. Thanks to these observations, we now have a better understanding of the impact of environmental and atmospheric conditions on the migration strategies of birds. These findings are important for the field of avian migration as it shows that other birds may also fly over the seas and oceans. The results not only provide a novel view of avian migration but also position birds as sensitive indicators of meteorological events such as cold fronts.

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Artificial skies: why insects get stuck circling lights at night

We have all seen groups of insects flying around porch lights and streetlamps. Scientists have some explanations for this phenomenon, including insects being drawn to light because they think it is a gap in the foliage, or perhaps the light is blinding, causing the insects to crash into it. Regardless of which idea you are drawn to, the fact that insects are attracted to light is a growing problem, especially as increasing urbanization is causing increased light pollution across the globe. Using high-speed, motion-tracking videos to study the flight patterns of insects flying near lights, Samuel Fabian and Huai-Ti Lin at Imperial College, UK, Pablo Allen of the Council of International Educational Exchange, Costa Rica, and Yash Sondhi and Jamie Theobald of Florida International University, USA, set out to discover why insects are drawn to artificial lights and why they seem to get stuck once there.

First, the researchers traveled to the Monteverde Field Station in Costa Rica to record the general flying patterns of 10 different orders of nocturnal insects in response to artificial light. Using two high-speed cameras with extra infrared lighting, the researchers filmed insects flying around an outdoor UV light that shone either horizontally, upwards or downwards. Fabian and colleagues found that insects generally flew at a right angle to the light source rather than towards it. This resulted, on average, with insects flying in a circle around the light. The team found that the night-time flight behaviors they recorded fell into three broad categories: orbit, stall and invert. The researchers described 'orbit' flight as the insect flying in an arcing pattern around the light, 'stall' as the insect flying upward, towards the light, and slowing down without swooping back downward, and 'invert' as the opposite of stall, where the insect goes up and then takes an abrupt nosedive. Knowing what these flight behaviors look like helped the team focus on the finer details of how these insects fly around light when flying in a controlled laboratory setting.

Focusing on four species, two day-time flying dragonflies and two night-time flying moths, the scientists filmed these insects flying around a light source in the laboratory. Attaching small markers near the wings of the insects, the team recorded their position and orientation during flight using four pairs of synchronised cameras arranged in a ring. Using this high-resolution, motion-tracking footage, Fabian and colleagues found that insects do not fly directly towards the light, but rather turn their backs toward it, causing them to fly in an arcing shape around the light source. The authors concluded that the insects use light to work out which way is up, even at night. Insects tilt their backs to where they perceive 'up' to be based on where light is coming from. In nature, this light comes from celestial sources in the sky and is generally upward. However, artificial light at night can be from the side or below. This causes insects to tilt their backs away from pointing up, toward the light resulting in the insects getting stuck circling the lights.

The results of this study, though satisfying to our curiosity, are troubling given that night skies across the world have never been more polluted by artificial light. Although Fabian and colleagues did not study how the light's distance away from the insect, its brightness and color affect this behavior, our brighter night skies are trapping insects around artificial light sources, undoubtedly keeping them from living their lives and making these animals easy prey.

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