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Long spider bodies under the sun

Spiders are underrated. We tend to think of them as creepy crawly cellar dwellers or as Halloween decor, but there is a lot more to spiders than that. Rather than hiding out in dark crevices, many spend their days fully exposed on their webs, enduring heavy rain, howling wind or bright sunlight. Spiders also come in a huge variety of shapes: some have very round, ball-like abdomens, whereas others have an elongated or cylindrical back end. With all this diversity in lifestyle and form, it's not surprising that spiders thrive in every terrestrial habitat, often with the aid of curious adaptations to the peculiarities of their home turf. Interested in the many ways that spiders live their lives and how they cope with environmental challenges, Leonardo Ferreira-Souza from the University of Brasilia, Brazil, and colleagues investigated how a spider's daily dose of sunlight shapes its body.

Ferreira-Souza and colleagues hypothesized that elongated abdomens were more common in spiders routinely exposed to the sun and that this feature protected them from overheating, as some spiders point the end of their abdomen towards heat sources such as the sun. For example, if a spider's abdomen is cylindrical, then this unusual posture could keep most of their body surface out of direct sunlight and help them stay cool. To test their idea, the team scoured museum and scientific archives for photos and illustrations of orb spiders – the most common spiral web-spinning spiders – from the Caribbean, Central America and South America, measuring the total area and roundness of as many spider abdomens as possible. They also classified each spider as either sun exposed or sun protected, where sun-exposed spiders were active during the day, typically soaking up the rays sitting on their webs, while sun-protected spiders were active at night or spent their waking daytime hours in shelters such as leaf litter.

Thousands of measurements later, it was clear that the sun-exposed spiders had more cylindrical body shapes on average than sun-protected spiders. The scientists then turned their attention to the physiological implications of the spiders' abdomen shapes, calculating how warm different shaped arachnids would get under natural conditions. They paid special attention to how often their simulated spiders exceeded two key temperatures: 35°C, a temperature that most spiders avoid, and 40°C, a temperature where many spiders show symptoms of overheating such as leg spasms or slipping into a coma. If the elongated body shape was adaptive for heat management, then cylinder-shaped spiders should be less likely to reach dangerously hot body temperatures.

As predicted, the cylinder-shaped spiders stayed cool. On a typical 30°C day, the body temperature of an elongated spider would only reach 33°C, whereas a round spider of the same size would hit a dangerous 40°C. By plugging in 10 years' worth of historical weather data, the researchers estimated that the round spider would experience 85 days per year at or above an uncomfortable 35°C, including 8 days when its body temperature would be critical at 40°C. In contrast, the simulated elongated spider had much fewer heat stress days, only reaching a body temperature above 35°C for 36 days per year and never experiencing a body temperature above 40°C.

Like many animals, spiders have adapted their bodies to survive the challenges of their habitat. Unlike many animals, at least unlike many vertebrates, spiders have literally changed the shape of their bodies as a thermoregulatory strategy, stretching out their abdomens over evolutionary time to protect themselves from overheating. Spiders are way cooler than we give them credit for!

doi:10.1242/jeb.243441

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Jamaican bats can smell food and drive themselves bananas

Imagine that you are approaching home. Suddenly, you come across the smell of your favourite casserole, and it is so strong that you could almost close your eyes and let the smell guide you. While humans can use their sense of smell to decide whether or not that new recipe they just tried is edible, other animals can also take advantage of sniffing around to make their way to delicious food. Now, we all know that bats excel at using echolocation, their unique navigation system to make their way around their environment. However, it turns out that

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Jamaican fruit-eating bats (*Artibeus jamaicensis*) can very much exploit their olfactory system to complement their echolocation system and find a delicious treat, such as a banana.

To expand on what we already know about Jamaican bats and their smelling capabilities, Alyson Brokaw and Michael Smotherman from Texas A&M University, USA, with Evynn Davis from Johns Hopkins University, USA, and Rachel Page from the Smithsonian Tropical Research Institute, Panama, collaborated in a fun new study where they set a group of Jamaican bats the exciting challenge of identifying a succulent banana using their sense of smell alone. Placing five stands (four holding banana-shaped sponges and another holding a real banana) in an almost-dark medium-sized chamber, Brokaw and her collaborators allowed the inimitable flying mammals to roam around the room in search of the true banana. However, bats are very smart and could just use their echolocation system to identify the real deal. So, to account for this, Brokaw and her collaborators performed a second experiment where they replaced the real banana with a fifth banana-shaped sponge soaked in a delicious banana-scented syrup and waited to see how the bats reacted.

Over the course of several days and multiple trials, Brokaw and colleagues measured the number of times the bat landed on the right target in both experiments, in addition to calculating the animals' instantaneous velocity and their vertical distance from the target before they decided to land on the true or fake banana scented with syrup. It turned out that the Jamaican bats were correct 87% of the time and selected the scented targets, whether they were the real deal or the banana decoy. Also, the bats tended to slow down and get as close as 6 cm above the targets, swooping low at least 2 or 3 times to take a good sniff before they decided to land on their prize.

So, bats can use their olfactory system to tease out the good from the bad targets by inspecting their options with their noses. Understanding how bats navigate their environment is important because it allows us to predict how changes in the landscape could have a direct impact on these animals. Bats are very clever animals: not only can they use spatial memory and echolocation to get a good idea of the landscape but they can also combine their olfactory and echolocation systems to decide which is the best banana hanging from the tree. Who knows, maybe Jamaican fruit-eating bats are as good at finding ripe bananas as pigs are at locating luscious truffles.

doi:10.1242/jeb.243479

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Lizard profiteers of climate change: ain't no mountain hot enough

Mountains host a variety of unique ecosystems and an incredible number of species because of the temperature changes that come with changes in altitude. However, warming caused by climate change throws a wrench into this system, with tropical mountains being especially vulnerable. Tropical ectotherms (species that rely on behaviour instead of metabolism to maintain their body temperature) may be especially in jeopardy because many already live near the upper limits of the temperatures that they can endure. The limiting factors for species living on tropical mountains are the amount of time when it is warm enough for them to be active to find food, and whether or not they will experience temperatures that are too hot, causing heat stress. A group of researchers led by Martha Muñoz from Yale University, USA, and her colleagues from other US universities investigated how a warming climate will affect three species of mountain anoles on the Caribbean Island of Hispaniola.

Initially, the team focused on two high-altitude species, black-throated stout anole (*Anolis armouri*) and the Cordillera central stout anole (*Anolis shrevei*), both of which live on their own mountain ranges on the Caribbean Island of Hispaniola, and a third, widespread species, the large-headed anole (*Anolis cybotes*), which lives throughout the island, but on the edges of broadleaf forests at lower elevations. Having previously investigated the lizards' basking behaviours, body temperatures and thermal preferences, the team used these observations to calculate how the lizards might behave at different environmental temperatures. They then built a detailed climate simulation to predict the temperatures that the lizards might experience when basking in the sun versus cooling off in the shade or when hiding while foraging. The team then linked the two models to predict how much time these *Anolis* species would be able to be active in different future climate predictions. Additionally, they looked at how close the predicted temperatures are to the upper and lower temperatures that these species can tolerate, as well as including predictions for how different types of forest will impact the conditions experienced by the reptiles living there.

Muñoz and her colleagues found that if climate change continues at its current pace, black-throated stout anoles and the Cordillera central stout anoles may be able to be active for an average of 441–472 h more per year than their current activity levels. This is because warmer environmental temperatures will reduce the number of cold mornings that the mountain lizards experience, which currently limits their activity in much the same way that you hesitate to jump out of bed if your room is freezing, but once the heating turns on, you're willing to move about. However, the increased temperatures experienced by the two mountain species won't be so extreme that the lizards are likely to overheat, simply because the slopes they live on are so cold. So, while this combination of predictions is great for the two species of high-altitude lizards, there may be some consequences in the form of the large-

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headed anole, which currently lives at lower altitudes. If the cloud forest that it inhabits moves up the slope as temperatures increase, this lower-altitude species may be able to invade the habitat of the higher-altitude lizards, directly competing with them for food and habitat.

Climate change is a double-edged sword; as some species enjoy the release from cold constraints, they may also be left simultaneously more vulnerable to invasions from species displaced by climate change. A species' survival depends on a multitude of factors; studies investigating the effects of climate change must account for many moving parts. In this study, Muñoz and her team looked at broad issues ranging from heat stress to habitat availability, and suggest that future studies take a multi-dimensional approach when assessing species' vulnerability to climate change to investigate the best potential avenues for conservation.

doi:10.1242/jeb.243440

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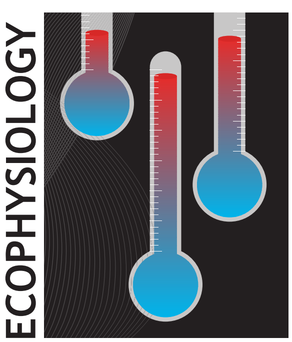
Late bloomers: southern salmons' life support



Biological diversity is important for keeping a community stable during environmental disturbances. But recently, scientists wondered whether members of a single species similarly benefit from diversity in individual characteristics, such as when they migrate? Most juvenile salmon spend many years in freshwater before heading out to sea to develop into adults. However, the Chinook of California's Central Valley live right at the species' southern limit. With river temperatures that are too hot and dams that block access to the cooler rivers up in the mountains, habitat is hard to come by. Instead, most Californian juvenile salmon migrate to the ocean as early as their first winter to avoid the scorching summer heat. The exception is a small group of juveniles in northern California. They delay migration like the Chinook of Washington and Canada because they have access to the only two rivers in the state with tolerable summer temperatures (Mill and Deer Creeks). A team of scientists from the USA, UK and France led by Flora Cordoleani from the University of California Santa Cruz, USA, wanted to know whether this diversity in individual migration patterns might make the population flexible to climate change?

From 2007 to 2018, Cordoleani and colleagues worked with the California Department of Fish and Wildlife to investigate the life history of adult Chinook that had returned to Mill and Deer Creeks to spawn. The scientists had the enviable job of collecting ear bones (otoliths) from the carcasses of the recently deceased. Freshwater and saltwater leave distinct chemical fingerprints in the layers laid down each year as the otoliths grow, revealing exactly when the fish departed on their ocean odyssey. George Whitman of the University of California Davis, USA, Corey Phillis of the Metropolitan Water District of Southern California, USA, and Peter Weber of Lawrence Livermore National Laboratory, USA, used 123 of these precious bones to investigate their composition and to reconstruct the daily growth rates and timing of migration for each fish. The team then grouped the fish into one of the three migration strategies based on when they left Mill and Deer Creeks. Early-migrating fish waited 2 weeks before leaving the river of their birth, whereas intermediate-migrating fish waited 3 months and late-migrating fish waited 6.5 months before departing. They then figured out how many individuals of each migration type were returning as adults each year and whether the proportion of fish using each migration strategy changed from year to year.

Correlating the fish's migration patterns with the weather, the team found that during wet years, roughly the same number of early, intermediate and late migrants returned to Mill and Deer Creeks. However, in years of extended drought and during ocean heatwaves, late migrants were essentially the only fish that could withstand the heat and return to the rivers of their birth (making up 77–100% of returning adults). California Chinook are all closely related, so this suggests that the late-migrating fish from Mill and Deer creeks can handle higher temperatures simply as a result of the environment they were raised in, rather than inheriting the ability to tolerate heat from their parents. With increased tolerance for high temperatures, these late-migrating individuals have a better chance of survival and act as the 'life support' for the northern California Chinook salmon during extreme climate years.

Sadly, projected increases in global temperatures will make finding comfortable river homes even harder for these fish. Alyssa FitzGerald from the University of California Santa Cruz, USA, ran computer simulations to predict future temperatures in the Central Valley river system. If average water temperatures increase by 1.0°C by 2080, even the late-migrating juveniles would lose more than half of the rivers and streams they currently inhabit. However, Cordoleani and colleagues propose a simple solution to the problem: provide access to higher elevation streams currently above dams. Removing dams could as much as triple the rivers available for all Chinook. By having diverse migration patterns, these salmon are trying their best to keep their populations afloat in the face of climate change. But California Chinook still might not be able to keep up with increasing temperatures – at least not without our help.

doi:10.1242/jeb.243442

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Bats avoid overheating through intermittent flying

Bats are remarkably versatile. Not only are they the sole mammal that has mastered the mystery of flight but they also have the ability to lower their body temperature to reduce their metabolic rate and conserve energy when the temperature drops. However, when bats are flying, their metabolic rate is considerably higher, causing their body temperature to rise. Yet, little is known about how bats prevent themselves from overheating during flight. Jinhong Luo from the Central China Normal University, China, Stefan Greif and Yossi Yovel from Tel Aviv University, Israel, and colleagues from Israel and Thailand, decided to monitor the body temperature of wild great roundleaf bats (*Hipposideros armiger*), which is one of the largest insect-eating bats, taking short intermittent breaks between flights while they hunt at night for moths, butterflies and beetles.

The team went out to Satun cave in Thailand and caught 18 bats using hand nets. Then, they attached a small temperature and motion sensor equipped with a GPS tracker to the backs of 10 bats, gently inserting the tiny temperature sensor beneath the skin to simultaneously record their temperature as they flew at night. Ten days later, the team successfully relocated five of the original sensors by following the GPS signal, discovering that four had successfully recorded the bats' body temperature, although only two of the motion sensors clearly showed their flight manoeuvres. In addition, the team tagged the eight remaining bats with the temperature and motion sensors alone and released the animals in a 3×2×2 m^3 room, letting them fly freely to collect more detailed information about the mammal's flight manoeuvres and body temperature. Once the experiments were complete, the team removed the tags, and re-released the bats into the wild.

After analysing the movements of the bats that had spent time in the laboratory, the team identified 55 flight bouts that lasted for about 48 s. Between these short flights, the bats would stop flying and take breaks on perches. The researchers then compared their activities with the skin temperature measurements and found that the bats that had experienced the fastest skin temperature rises had the highest skin temperatures, while the bats that had slower temperature rises ended up with cooler skins. The researchers then compared those findings with the situation of the bats in the wild and found a similar skin temperature pattern. Also, when the team checked the highest skin temperatures of both groups of bats, they reached approximately 40°C, fortunately well below the lethal level of 44–45°C.

The researchers suspect that the short intermittent flights used by the hunting bats may help the animals to avoid potentially lethally high body temperatures. Additionally, when great roundleaf bats take breaks on a perch between foraging bouts, the bats probably reduce the amount of energy that they use, compared with the amount of energy they would consume if continually flying and searching for prey. Now that Luo, Greif and colleagues have successfully measured the skin temperature of wild flying great roundleaf bats, other researchers could use the same strategy to find out how bats that thrive on different diets, such as fruit or even scorpions, keep their temperature down when performing the most metabolically demanding activity known. Alternatively, scientists could look at the body temperature of smaller bats as they go about catching insects, to find out how body size impacts how they regulate their temperature while on the wing.

doi:10.1242/jeb.243439

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