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# Birds Ruffled by Big-City Lights

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OUTSIDE JEB

# Flapping wings help insects stay stable

Insects are remarkably agile fliers capable of complex aerial manoeuvres and hovering in turbulent environments. In fact, conventional ways of generating lift, such as those used by airplanes, would not be sufficient to keep them airborne, so they rely on mechanisms such as bound vortices on the leading edge of their wings to help them fly. Despite these exotic mechanisms, for years it was thought that insects were unstable while hovering. Previous analyses of how they fly relied on averaging the forces produced by their flapping wings. Based on these methods, it was thought that flapping fliers such as hawk moths would be vulnerable to toppling head over heels because of this instability. It was assumed that averaging the forces over time was a fine approach to study insect flight, as the frequency of the flapping wings was much higher than the time scales of the body movements. Therefore, it was thought that insects must use sensory feedback – either perception of the body's position in space or vision – to stabilize their flight. However, a team of researchers based in the USA recently reinvestigated the flight of a hawk moth and found that they may be more stable than previously thought.

Haithem Taha and colleagues from the University of California Irvine, the University of North Carolina and the Pacific Northwest National Laboratory used a method called chronological calculus, which allowed them to study the time-varying effects inherent to the flapping of the wings during flight. The new technique allowed the team to identify a novel way for moths to prevent themselves from toppling by precisely synchronizing the oscillations of the body and the wings. This synchronization generates turning forces, which are used for correction when they tip unexpectedly after encountering turbulence or colliding with another object.

Next, the team tested their revised model of hawk moth flight to find out how well the real insects coped when tipped during a collision by firing a pellet at individuals as they approached an artificial flower. Filming the disturbances on high-speed 3D videos, the team then tracked the wing and body motions as the moths recovered, revealing that the predicted synchronizations occurred in real flight tests as hawk moths stabilized their flight.

Finally, the researchers used chronological calculus to compare how stability changes in seven other flying organisms, from hummingbirds to fruit flies, whose flapping frequencies varied from tens to hundreds of wing beats per second. For animals such as hawk moths and hummingbirds, which flap their wings at approximately 20 to 30 wing beats per second, the effect of the stabilization provided by the synchronized body and wing oscillations is stronger than for fliers operating at higher frequencies, such as the fruit fly. This demonstrates that sensory feedback still likely plays a role in stabilizing flight for insects that really buzz about.

Insects and other flapping fliers continue to amaze us with new revelations about how they stay aloft. It turns out that the very act of flapping helps them stabilize against pitch disturbances that are likely present in the windy skies they fly through. These findings could completely revise our understanding of how flapping fliers control and stabilize their flight. While insects still likely require active control and sensory feedback to fly, perhaps their passive stabilization mechanisms will inspire the mechanical design of robotic fliers and relax their computational requirements.

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**Taha, H. E., Kiani, M., Hedrick, T. L. and Greeter, J. S. M.** (2020). Vibrational control: a hidden stabilization mechanism in insect flight. *Science Robotics* **5**, eabb1502. https://robotics.sciencemag.org/content/5/46/eabb1502

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# Combining farming practices drastically shrinks blue orchard bee populations

Blue orchard bees pollinate fruit trees in orchards across the United States. However, multiple farming practices pose a threat to the bees' survival. Though both pesticides and changing landscapes can affect survival of bees in the lab, little is known about their combined effects in the wild. Recent work by Clara Stuligross and Neal Williams from the University of California Davis, USA, suggests that the harmful effects of pesticides are worsened when bee food supplies are limited.

Stuligross and Williams first tested how the number of flowers available for foraging affects the bees' reproduction. The team built flight cages in a North Central California field for the bees to live in. Some cages had access to more flowers than the bees needed, while other cages had just enough flowers for the bees' survival.

The duo noticed that female bees in flight cages with fewer flowers not only took longer to build their nests, but also spent less time at them and their brood were also a little smaller. These effects might be because there was only enough food available to keep the adults alive and not enough to feed the larvae or to give the bees the energy needed to tend to their young. This suggests that farming practices that reduce the number of flowers could harm bee reproduction.

Next, the researchers examined the effects of an insecticide – imidacloprid, commonly used in California fruit orchards – on the female bees' nesting behaviours. Stuligross and Williams drenched the soil in the flight cages with the maximum amount of imidacloprid allowed in Californian orchards before letting the bees inside. Similar to bees with less food, bees exposed to imidacloprid took longer to make their nests and spent less time there. This might be because the chemical is known to slow the development of females' ovaries, which could affect the hormones that trigger nesting behaviours and egg laying. Yet, larval bees exposed to imidacloprid were larger than those not endangered by the chemical. The researchers think that this difference in size might be because insecticide-affected bees had fewer offspring and thus had the opportunity to give each of their surviving progeny more food than their pesticide-free counterparts.

Stuligross and Williams then tested how pesticide use and the number of flowering plants might work together to affect the bees' reproduction, and found that pesticide use and food limitation combined reduce the number of larvae by nearly 60%. If there are fewer offspring, then the number of adult bees in a colony will shrink over time and this decline is worsened by the fact that pesticides result in a population of almost all male larvae. Without females, blue orchard bees cannot reproduce, worsening the decline of the adult bee population. Taken together, these results suggest that combining harmful pesticides with fewer flowering plants could cause bee populations to decline and, eventually, go extinct.

However, the researchers only detected imidacloprid in the pollen that the bees brought home in two out of the eight flight cages. Imidacloprid might have occurred at such low levels in the pollen that the bees consumed that it was not detected in the researchers' analyses; however, the scientists are concerned that even tiny doses could have a significant impact on bee health.

Farming practices should include ways to protect the bees that pollinate farm crops because multiple stressors can combine to have catastrophic effects on bee populations. If there are fewer blue orchard bees pollinating farmers' trees, there will be less fruit to go round for all of us.

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**Stuligross, C. and Williams, N. M.** (2020). Pesticide and resource stressors additively impair wild bee reproduction. *Proc. R. Soc. B* **287**, doi:10.1098/rspb.2020.1390

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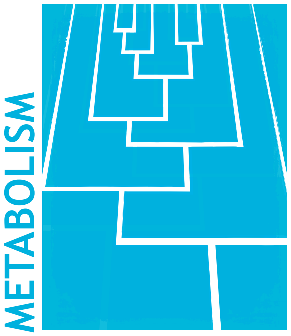
## Slow and steady climbs the waterfall



When Aesop penned his famous tale of the tortoise and the hare, he probably wasn't thinking about the waterfall-climbing gobies of Reunion Island. Not one, but two species of Sicydiinae gobies call this place home, embarking on an arduous journey upstream (literally!) to find safe, freshwater pools in which to spawn. Slow and steady, *Sicyopterus lagocephalus* inches its way up, secured to the slick rocks by sticky suckers on its belly and mouth. In contrast, *Cotylopus acutipinnis* leaps ahead by flicking its tail and pectoral fins, much like Aesop's hare. Unfettered by its oral sucker, *C. acutipinnis* covers a lot of ground in a short time, but takes long rest periods between leaps. Considering these radically different approaches to life's obstacles, Raphaël Lagarde, currently a postdoctoral fellow at the University of Perpignan, France, and colleagues from Reunion Island, Madagascar and Canada wanted to know which goby was the better mountaineer and why.

Racing requires a racetrack, so the researchers set a 2.4 m ramp at a 45 deg angle, lined it with sandpaper and pumped water over it. Both gobies managed to climb the simulated waterfall, but overall, the tortoise-like *S. lagocephalus* climbed three times faster than the hare-like *C. acutipinnis*. Though *C. acutipinnis* could easily out-sprint *S. lagocephalus*, it wasn't enough to make up for the extra time spent resting: *C. acutipinnis* spent over 90% of its time sitting motionless, whereas *S. lagocephalus* only spent about two-thirds of its time on breaks.

Next, the researchers focused on the muscle powering their gobies' movements, hypothesizing that their physiology would match their climbing style. They predicted that slow and sustained exercise, like the steady inching of *S. lagocephalus*, would be powered by aerobic pathways. In contrast, the fast and explosive 'power burst' style of C. *acutipinnis* should rely on anaerobic pathways. Supporting these predictions, the slowly inching *S. lagocephalus* had higher activities of enzymes involved in carbohydrate metabolism – citrate synthase, pyruvate kinase and lactate dehydrogenase – than *C. acutipinnis*. The muscles of *S. lagocephalus* had bigger metabolic engines for aerobic activity – exactly what they needed to keep on keeping on.

Finally, the researchers examined the fuels needed to power the muscle's metabolic engine: glycogen and fats, as well as lactate, which is produced when muscles dip into anaerobic pathway. Both gobies had similar amounts of glycogen and fats in their muscle, suggesting that running out of oxygen didn't explain the lengthier pauses of *C. acutipinnis*. Both species also kept lactate levels low, even after an intense climb, suggesting that their chosen rest periods were enough to avoid overexerting their muscle. The data also hinted at an interesting aspect of goby life history – neither species had impressive fuel reserves, suggesting that wild gobies probably snacked on their way to the top.

Slow and steady wins the race, whether you are a tortoise or a waterfall-climbing goby. *Sicyopterus lagocephalus* crawled across the finish line ahead of *C. acutipinnis*, supported by a more sustainable form of locomotion and more powerful metabolic machinery. As both species search for breeding sites throughout the year, the quick pace of *S. lagocephalus* may lead to competitive advantage. Like another old proverb, perhaps the early fish gets the pool.

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## Whoosh! Springy-bounce spider webs

Slingshot spiders certainly live up to their names. Weaving webs in the shape of a satellite dish with the middle caved in, the finishing touch is a single silk thread, running from the middle of the web to a nearby location to anchor the structure in place. This line – the tension line – works like a bungee cord that the spider stretches to extend the parabolic shape and then releases to make the web spring forward, trapping insects in its path to ensure the spider's next meal. For many years, scientists have been interested in slingshot spiders, but relatively little was known about how the spiders work the tension line to make their webs bounce. To learn more, Symone Alexander and Saad Bhamla from the Georgia Institute of Technology in Atlanta, USA, decided to take a closer look at the catapulting spiders.

In the Peruvian Amazon rainforest, Alexander and Bhamla searched among dead branches and leafy plants to locate the spiders and their webs in their natural habitat. With high-speed cameras trained on the spiders, the researchers snapped their fingers close to the webs to trigger the spiders into releasing the tension line and catapulting their webs forward.

After analysing 15 videos of four spiders releasing their webs, the team found that the spiders used the springiness of their webs to achieve impressively high speeds. During the slingshot motion, the web reached a whopping acceleration of up to $1300\ \mathrm{m\ s^{-2}}$, which is roughly 130 ***g*** forces or about 10 times the top acceleration experienced by a cheetah at the start of a standstill sprint. From this massive acceleration, the web reached a top speed of $4.2\ \mathrm{m\ s^{-1}}$ in just 6 ms – only a fraction of the time it takes to blink an eye – allowing the spiders to catch unsuspecting insects as the web shoots forward.

Nimbleness is key here, with the spider making use of all eight of its legs – and then some. As the spider sits on the back side of the web facing the tension line, its four hindlimbs hold onto the web while all four forelegs grab the tension line. To set the web in motion, the spider lets go of the tension line, which releases the web, allowing it to shoot forward. However, with all of its legs already on duty, the spider allows the tension line to slide between its pedipalps – small leg-like appendages near the jaws – which allows it to quickly grab a hold of the line to restart the process anew.

But how does the spider engineer its ballistic web to reach such impressive speeds? Analysing the springiness of the spiders' web lines, the team found that the silk was particularly efficient at converting stretch into bounce, even outperforming other biological and man-made materials designed to be elastic. So while the spiders may be exceptionally imaginative to use their webs so creatively, credit must also go to the springy silk that puts bounce into the structure.

Alexander and Bhamla provide new insight into how the slingshot spider uses its web like a catapult to catch insects. The team is also curious to learn more about the molecular structure that makes the silk so springy in the hope that we can use the lesson to engineer materials with superior springiness. As it currently stands, only slingshot spiders get to take advantage of their silk to go on their whippingly fast rides.

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## Birds ruffled by big-city lights

The blazing lights of Times Square in New York City may be impressive for tourists, yet this blindingly bright attraction can cause problems for urban wildlife. Artificial light at night, typical of cities and suburban areas around the globe, can cause problems for the animals that we share space with, although the impact on local wildlife is often disregarded. Given the current global COVID-19 pandemic, understanding how stressors, such as artificial nocturnal light, alter infectious disease transmission is now even more pressing. So, Daniel Becker and colleagues from Indiana University in the USA delved into this question, looking at how persistent artificial light at night alters immunity and infection risk in wild animal communities.

Becker and colleagues suspected that migratory species may be especially vulnerable to artificial nocturnal light, as they frequently migrate at night and use urban and suburban habitats as resting spots along their route. To test this theory, the team chose to study the dark-eyed junco (*Junco hyemalis*), a songbird which has populations that migrate and others that stay put to breed. Both of these population types are susceptible to blood-borne parasites during their summer breeding season that are transmitted by blood-sucking insects (such as mosquitoes), that initially cause a short infection, but can then remain dormant for months before rearing their ugly head when the host is either stressed or busy with other tasks, such as reproduction. The researchers suspected that the stress associated with artificial nocturnal light could make the birds more vulnerable to infection relapses, and that these effects would be stronger in the migratory birds than in their stay-at-home counterparts, as migration can suppress the immune system.

To test these ideas, the researchers rounded up resident and migratory juncos from their summer-time roosts in the Appalachian Mountains, USA, before transporting them back to an indoor aviary at Indiana University. For over 6 months, half of the migrants and stay-at-home birds were exposed to artificial light at night, while the remaining birds experienced a natural light cycle. Throughout this time, the researchers looked for signs of changes in the birds' immunity (by looking at the number of white blood cells in their blood) as well as the risk of infection relapse, by keeping track of the number of parasites in the birds' blood over time.

Becker and colleagues found that nocturnal artificial light increased the total number of white blood cells in both resident and migratory birds, indicating that their immune systems were surging, and when the researchers looked at the birds' parasite numbers, these spikes weren't surprising. Following exposure to man-made nocturnal light, the number of parasites in the birds' blood also boomed. This effect could be due to changes in the hormone melatonin, which is secreted when it is dark and boosts the immune system. Artificial light at night may suppress melatonin production, thus supressing the immune system and increasing susceptibility to infections.

The negative impacts of artificial light at night on wildlife in urban and suburban areas could be minimized by urban planners devising alterations to city lights in collaboration with physiologists. Possibilities include shifting street lighting to a yellower or redder tone, reorienting lighting structures to project light down, rather than up, and restricting the use of bright lighting at night during key times of year – such as those coinciding with annual migrations – to reduce the impacts of man-made light on nocturnal wildlife in and around our cities.

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