Bee populations at risk of one-two punch from heat waves, pathogen infection

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A blue orchard bee (Osmia lignaria) is one of two species of solitary bees studied by a team of researchers led by Penn State. It was the first study to examine how extreme heat waves affect the host-pathogen relationship between solitary bees and a protozoan pathogen (Crithidia mellificae). Credit: Robert Webster

The historically high heat waves that gripped the southwest United States and southern Europe this summer are causing problems for more than just humans. Extreme heat waves affect pollinators and the pathogens that live on them, creating a mutual imbalance that could have major economic and public health consequences.

A global research team led by Penn State was the first to study how extreme heat waves affect the host-pathogen relationship between two species of solitary bees (Osmia cornifrons and Osmia lignaria) and a protozoan pathogen (Crithidia mellificae). The researchers recently published their findings in the journal *Frontiers in Ecology and Evolution*.

The researchers found that the one-two punch of extreme heat exposure and prior infection led solitary bees, which account for over 90% of the roughly 4,000 species of bees in North America, to be less likely to forage for food. If bees don't forage, they don't eat, and importantly for humans, they don't pollinate crops that are vital to the global economy and food security.

"We are now experiencing the highest temperatures in recorded history," said Mitzy Porras, a postdoctoral researcher in Penn State's College of Agricultural Sciences and lead author of the study. "These heat waves are lasting three, or even four days, which is a long period of heat tolerance for bees. Then, when you combine that with prior infection from a pathogen, we're looking at two factors that can severely negatively impact pollinator populations."

The researchers devised an experimental method for testing that Porras calls "thermal boldness," the amount of heat a bee can withstand in order to move to a food source. The bees were placed in a tunnel. On one side of the tunnel was a chamber with temperatures akin to what would be experienced in a summer heat wave, and on the other side of the hot chamber was a meal of sugar water and pollen. The team found that bees, which had previously been infected with a common protozoan pathogen, were far less tolerant of heat and much less likely to take the risk of passing through the chamber to eat.

In general, they found that the heat negatively impacted both the bee host and its pathogen, but the host bore the brunt of it. Exposure to heat decreased the bees' thermal boldness and their heat tolerance, whereas the pathogen's growth rate was only slightly negatively affected by heat.

"These asymmetrical relationships between organisms are often overlooked when studying climate impacts, but they are essential if we want to understand what is really going on," Porras said. "When we looked at the host and pathogen in tandem, we found that infection greatly reduces heat tolerance in the host—a finding we wouldn't have discovered if we had only been studying bees."

The researchers found that a healthy bee could tolerate a heat wave of 109.4 degrees Fahrenheit, but after infection its tolerance was reduced to 98.6 degrees Fahrenheit.

"Our results shed light on the implications of extreme heat waves on host–pathogen dynamics under a warmer world," said co-author Ed Rajotte, professor emeritus of entomology at Penn State. "We're not going to see a simple, linear change as the climate warms. Every organism will respond differently and the relationships between organisms will be fundamentally altered. If we're going to try to predict the impacts of climate change, relationships matter. There are real consequences to changes in our ecosystems and we must understand the subtleties if we are going to prepare ourselves for the reality of a changing climate."

Solitary bees, often called the workhorses of the pollinator world due to their high foraging capacity, live for roughly a year, but are only active outside their nests for two to four weeks, for example, in early spring. They do a lifetime of pollinating in less than a month, Rajotte explained.

For humans, a three or four-day heat wave may just be an uncomfortable blip, but for a solitary bee, it can represent a quarter of the total time they are active outside their nests—and can severely affect their fitness for mating, pollinating and producing offspring. The researchers demonstrated that their health is even further jeopardized if they have been previously infected with a pathogen.

The team concluded that extreme heat exposure reduces the bees' heat tolerance generally, but heat waves exacerbated the adverse effects of infection on the bees' thermal physiology and ultimately affected their behavior.

"We have to think about the big picture," Porras said. "Climate change is not just impacting species; it is impacting the relationships between species and that could have huge implications for human health and the planet as a whole."

Other Penn State co-authors on the paper are David Biddinger and Sharifa Crandall. The other authors are Carlos Navas and Gustavo Agudelo-Cantero of the University of São Paulo; Michel Geovanni Santiago-Martínez of the University of Connecticut; and Volker Loeschcke and Jesper Givskov Sørensen of Aarhus University in Denmark.

More information: Mitzy F. Porras et al, Extreme heat alters the performance of hosts and pathogen, *Frontiers in Ecology and Evolution* (2023). DOI: 10.3389/fevo.2023.1186452

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