Bee body mass, pathogens and local climate influence heat tolerance

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A female squash bee is captured in a tube in Pennsylvania Furnace. Researchers collected bees from 14 sites across the state to evaluate how bee size, sex and parasite pressure interact with a variety of local climate conditions and soil characteristics. Credit: Laura Jones

How well bees tolerate temperature extremes could determine their ability to persist in a changing climate. But heat tolerance varies between and within populations, so a research team led by Penn State entomologists examined bee physical traits—such as sex differences in body mass—to understand how these traits interact with environmental conditions, pathogens and other factors.

In a study published recently in *Ecology and Evolution*, the researchers measured body mass, local climate and pathogen intensity to assess how these factors influence heat tolerance and its population-level variation among individuals of the species Xenoglossa pruinosa, commonly known as the hoary squash bee. They found that variation in heat tolerance was influenced by size, sex and infection status of the bees.

"Small-bodied, ectothermic—or cold-blooded—insects are considered to be highly vulnerable to changing climate because their ability to maintain proper body temperature depends on external conditions," said study author Laura Jones, who led the research as a doctoral candidate in ecology at Penn State and is now a postdoctoral fellow at the University of Texas at Austin.

"Understanding how organisms tolerate temperature extremes is critical for assessing the threat climate change poses to species' distribution and persistence."

Jones noted that there is growing interest in studying the heat tolerance and acclimation capacity of ectotherms in the face of changing abiotic conditions such as ambient temperature.

"But few studies have examined biotic impacts, such as pathogen infection, on thermal tolerance in natural populations in combination with abiotic factors," she explained. "In addition, physical traits such as body size or fat content can impact how organisms tolerate temperature, so it's vital to consider individual condition, as well as the abiotic and biotic factors that individuals experience in natural environments, when evaluating the heat tolerance of populations."

A pollinator of cucurbit crops such as squash and pumpkin, the hoary squash bee is a solitary species that exhibits sex differences in physiology and behavior, according to the researchers. Females are larger than males and collect pollen for offspring in the morning through midday. The females nest underground, which buffers them from variations in air temperature, although soil texture may affect the degree of thermal buffering as sandy soils have a lower heat capacity.

The males, in contrast, are smaller, forage only for nectar, and buffer themselves from heat by retreating into wilted flowers after they finish foraging at midday. So, males are exposed to more variable ambient temperatures than females during the day and night.

The researchers hypothesized that the bees' heat tolerance would increase with body size; that male heat tolerance would increase with ambient temperatures above ground whereas female heat tolerance would increase with sandier soils; and that parasite infection would reduce heat tolerance.

To test these hypotheses, the researchers collected squash bees from 14 sites across Pennsylvania that varied in mean temperature, precipitation and soil texture. They measured individuals' critical thermal maximum—the temperature above which an organism cannot function—as a proxy for heat tolerance and determined the relative intensities of three parasite groups: protozoan parasite trypanosomes, bacterial pathogen Spiroplasma apis and microsporidian parasite Vairimorpha apis.

The team found that body size, environmental temperature and parasite infection have context- and sex-dependent effects on heat tolerance in squash bees.

"Although both sexes showed a positive correlation between heat tolerance and size, male squash bees had a greater change in their critical thermal maximum per unit body mass than females, suggesting that there may be another biological trait influencing the impact of body mass on heat tolerance that differs between the sexes," said study co-author Margarita López-Uribe, associate professor of entomology and Lorenzo L. Langstroth Early Career Professor in Penn State's College of Agricultural Sciences.

The study indicated that average daily maximum temperature, precipitation and soil texture did not predict critical thermal maximum. However, the results did show that where average maximum temperatures were highest, the variation in heat tolerance among individuals was lower, suggesting that extreme temperatures were "filtering out" individuals with high and low critical thermal maximums, the researchers said.

"Many bee species can actively control their body temperature independently from ambient temperature conditions and thus potentially mitigate effects of temperature extremes," said co-author Rudolf Schilder, associate professor of entomology and biology in the College of Agricultural Sciences and the Eberly College of Science. "But whether squash bees engage in such behavior is unknown."

Of the three parasites measured, only trypanosomes influenced heat tolerance—and only among female squash bees.

"This impact of parasite infection on female thermal tolerance is particularly concerning given that population growth depends on female fertility, and females are typically already less abundant than males," López-Uribe said.

Overall, Jones said, the study contributes to growing evidence that small-bodied invertebrates' ability to adapt or acclimate their heat tolerance to local climate conditions is limited and depends on several factors.

"Given this, it is critical to identify the populations that are at risk under future climate scenarios," she said. "We suggest that future research assesses the thermal tolerances of populations across a species' distribution to identify those that are most vulnerable to local extinction."

More information: Laura J. Jones et al, Body mass, temperature, and pathogen intensity differentially affect critical thermal maxima and their population-level variation in a solitary bee, *Ecology and Evolution* (2024). DOI: 10.1002/ece3.10945

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