How do temperature extremes influence the distribution of species?

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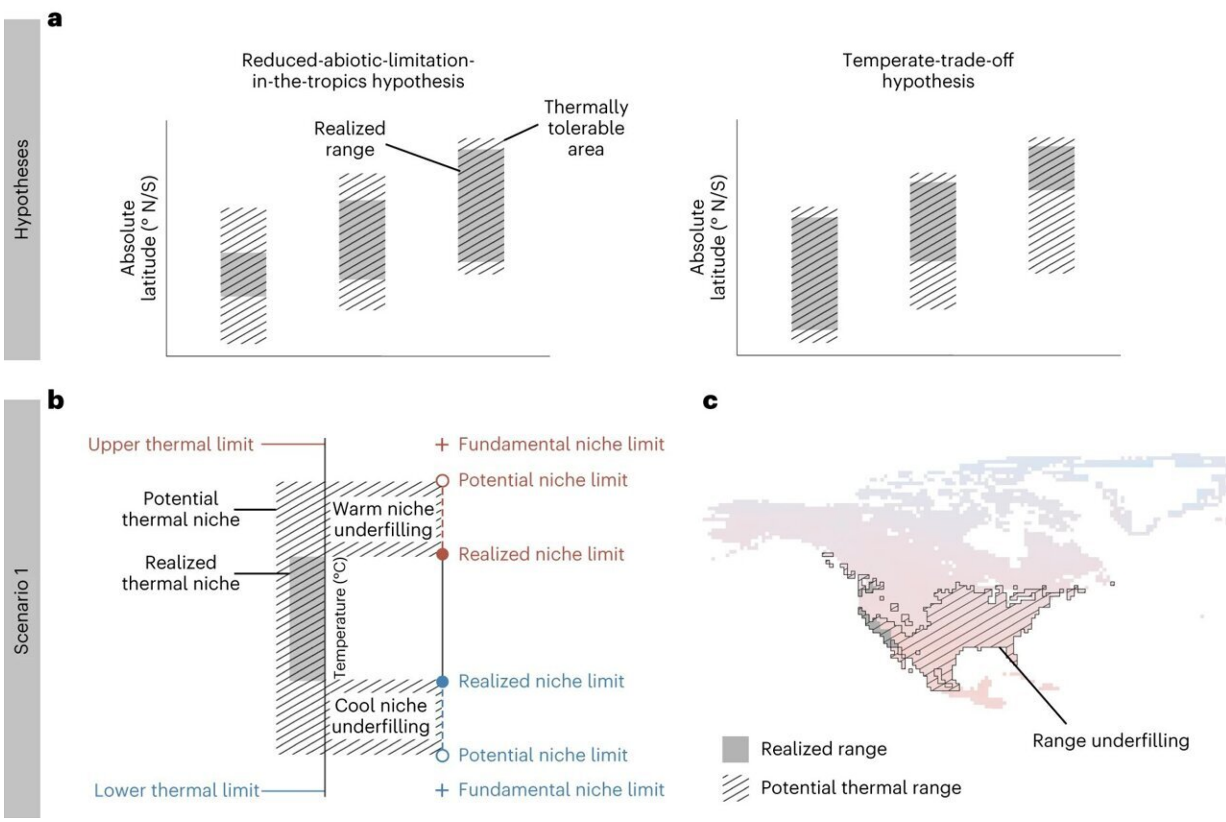

Predictions and definitions of thermal niche filling projected in thermal and geographic space. **a**, The reduced-abiotic-limitations-in-the-tropics hypothesis (left) predicts that stronger antagonistic species interactions in the tropics will exclude lower latitude species from occupying more thermally tolerable habitat at either range edge compared to higher-latitude species, while the temperate-trade-off hypothesis (right) predicts that a trade-off between cold adaptation and performance will cause higher-latitude species to be excluded from thermally tolerable habitat towards the equator. **b–e**, Two explanatory scenarios (1, **b** and

c; 2, **d** and **e**) illustrate potential and realized overlap in thermal space (**b** and **d**) and geographic space (**c** and **e**). **b**,**d**, The fundamental thermal niche is defined by the physiologically determined maximum (red) and minimum (blue) thermal tolerance limits, the difference between which defines a species' thermal tolerance breadth. A species' potential thermal niche is the extreme body temperatures within its fundamental thermal niche that it can experience (given constrained thermoregulatory behavior) across the encounterable habitat (here defined as the landscape or seascape contiguous with the species' realized range). A species' realized thermal niche is the extreme body temperatures it can experience throughout its realized range. Potential thermal niche limits differ from fundamental thermal limits when temperatures within the fundamental niche are not found in the current climate across the accessible habitat. **c**,**e**, A species' realized range encloses its observed extent of geographic occurrence, while its potential thermal range encloses the areas of available habitat where extreme body temperatures remain within the species' fundamental thermal niche limits. A species might not occur in all available niche space (niche underfilling, **a**; range underfilling, **b**) or might appear to occur beyond the available niche space if its thermal tolerance limits underpredict its geographic distribution (niche underprediction, **c**; range underprediction, **d**). Credit: *Nature Ecology & Evolution* (2023). DOI: 10.1038/s41559-023-02239-x

As the planet gets hotter, animal and plant species around the world will be faced with new, potentially unpredictable living conditions, which could alter ecosystems in unprecedented ways.

A new study from McGill University researchers, in collaboration with researchers in Spain, Mexico, Portugal, Denmark, Australia, South Africa, and other universities in Canada, investigates the importance of temperature in determining where animal species are currently found to better understand how a warming climate might impact where they might live in the future.

To find out, the researchers tested the role of temperature as a factor that could limit a species' potential habitat range. They compared the temperatures and areas where 460 cold-blooded animal species currently live to the temperatures and areas where they could live based on their tolerance to temperatures.

They found that, unlike species living in the ocean, land animals such as reptiles, amphibians, and insects have habitat ranges that are less directly impacted by temperature. The higher a species is in latitude, the lower its tendency to live in areas near the equator with temperatures they could tolerate, the researchers say. This means that, instead of tolerance to temperature, negative interactions with other species—like with competitors or parasites—could be what keep these species away from this potential habitat.

"It was not surprising to find that temperature doesn't always limit species ranges, but what was surprising was that, despite the complexity, we found general patterns in the role that temperature plays across species," said lead author of the study published in *Nature Ecology & Evolution* and Ph.D. student in the Department of Biology, Nikki A. Moore.

"This research helps us to understand general patterns in how sensitive the distributions of different cold-blooded animal species might be to changes in temperature, which will help us to predict how the global distribution of species will change because of climate change."

A pattern that predicts species distribution

The pattern that Moore and colleagues found helps resolve two conflicting hypotheses about the distribution of life on earth.

"While it had long been thought that species ranges are less limited by temperature and more limited by species interactions in the tropics, the new work shows that higher-latitude species are increasingly excluded from their potential ranges in the tropics, supporting the idea of a trade-off between broad thermal tolerances and performance in the tropics," said Moore.

While these results provide insights into the sensitivities of species in different realms and across latitudes to climate change, the next step for this research is to test these predictions using actual observations of species range shifts, the researchers say.

The researchers say predicting and testing how species distributions respond to temperature requires on good observations of where species live. Anyone can get involved in contributing to our knowledge of species distributions through citizen science, using applications such as iNaturalist.

More information: Nikki A. Moore et al, Temperate species underfill their tropical thermal potentials on land, *Nature Ecology & Evolution* (2023). DOI: 10.1038/s41559-023-02239-x

Provided by McGill University