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Is thermal adaptation genetically limited?



Earth's biodiversity is severely threatened by human-induced climate change. It is fairly trivial to mention that most organisms would be pushed either to evolve or migrate to new locations. Some current biodiversity models used to assess the vulnerability of species to climate change ignore the capacity of populations to respond by genetic adaptation and may grossly overestimate species' extinction risks. However, recent empirical research with a variety of cold-blooded animals suggests that heat tolerance has limited evolutionary potential when individuals are assayed in the lab under "ecologically realistic" conditions. If true, this would constraint genetic responses to rising temperatures and adds more pessimism to an already alarming situation. Our research shows that recent claims on the limited evolutionary potential in organisms' heat tolerance derives from a conceptual confusion between what we want to measure and what we are actually measuring in experiments.

Researches concerned with the ability of organisms to cope with rising temperatures routinely estimate their critical upper thermal limits placing individuals under acute constant stressful temperatures or subjecting them to more realistic conditions where temperature is gradually increased until individuals are knocked down (so-called ramping assays). The problem with ramping protocols is that results depend on the rate of warming, with higher heat tolerances usually observed when fast warming rates are used in experiments.

This has raised some concerns because natural warming rates are typically slow, and several authors claim that upper thermal tolerance limits may have been overestimated. An additional experimental observation is that the amount of heritable genetic variation for heat tolerance dramatically drops when “ecologically realistic” assays with slow ramping rates are performed. This has led to the conclusion that natural populations exhibit low adaptive potential for upper thermal limits under relevant rates of temperature change.

However, the real problem is that the parameter CT_{max} researchers want to estimate is not constant but changes during a thermotolerance assay according to the experimental conditions. We have developed a physiological model that can accurately replicate the empirical observations. The model clearly shows that there are various confounding effects when estimating heat tolerance and that many experimental protocols, particularly those that use “ecologically realistic” slow ramping rates, produce highly unreliable underestimates.

In our simulations to artificially select for increasing heat tolerance we have combined the physiological model with genetic models for quantitative traits. The results show that the evolutionary response of the underlying “real” upper thermal limit (CT_{max}) is independent of the methodology used in the experiments. However, what researchers estimate and wrongly call “upper thermal limit” does not seem to appreciably increase after selection when slow ramping rates are used.

Our theoretical approach makes it clear that the apparent contradiction stems from a conceptual confusion between what we actually measure (“estimate”) and what we would like to measure (“parameter”). The problem gets worse and worse as warming rates slow down and approach to “ecologically realistic” scenarios. The take home message is clear: when dealing with physiological measurements as organisms’ tolerance to high temperatures, do not blindly trust what you see. Our results are good news because adaptive genetic responses for increasing upper thermal limits under the current scenario of global warming may be higher than acknowledged in recent studies.

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References

Keeping pace with climate change: what is wrong with the evolutionary potential of upper thermal limits? Santos, M.; Castañeda, L. E.; Rezende, E. L. *Ecology and Evolution*, 2012, 2:2866-2880.

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