

## Climate change: on the pathway of heat-induced reproductive disaster?

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Dear Editor:

Human-driven climate change generates extreme weather events, a well-known consequence of global warming. This leads to increased exposure of most living beings to higher temperatures, resulting in longer, more frequent, and more intense heat stress (HS) periods. This jeopardizes the welfare and survival of animals, negatively affecting the process that connects generations and ensures subsistence and natural selection: reproduction. This letter aims to draw attention to the impact of increasing HS on animal reproductive capacity and the potential alternatives to address this phenomenon.

With rising temperatures in most regions worldwide, HS will increase in many animals, including humans. This will occur even if we achieve the goal of limiting global temperature rise to no more than 1.5 °C by the year 2100, relative to pre-industrial levels, as set in the 2015 Paris Agreement<sup>(1)</sup>. Roth<sup>(2)</sup> indicates that HS, upon inducing cellular stress, triggers both indirect (e.g., systemic physiological alterations) and direct (e.g., perturbation of gametes, embryos, and reproductive tissues) negative effects on animal reproduction. In this context, the fertility of insects,<sup>(3)</sup> aquatic organisms,<sup>(1, 3, 4)</sup> amphibians,<sup>(5)</sup> reptiles,<sup>(6)</sup> birds,<sup>(7)</sup> mammalian pets,<sup>(8)</sup> cattle,<sup>(2, 9, 10)</sup> wild mammals,<sup>(11)</sup> laboratory mammals,<sup>(12)</sup> non-human primates,<sup>(13)</sup> and humans<sup>(4)</sup> is threatened by elevated temperatures. Consequently, given the unavoidable increase in HS, if this trend continues, potentially all animal groups are at risk of experiencing at least partial declines in reproductive capacity worldwide. This scenario will endanger the production of food and goods from animal sources, affect animal welfare, and potentially threaten the survival of animal populations, including humans.

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To mitigate widespread animal reproductive failures due to excessive heating, or to prevent them, alongside the coordinated environment-oriented efforts by governments, private industry, scientists, and the general public to reduce global warming, modifications in the management of animals, or their gametes and embryos, are necessary. For instance, Hansen<sup>(9)</sup> suggests the following alternatives to mitigate the negative effects of HS on reproduction in farm animals: diet pattern changes; active or passive cooling systems; genetic selection or transgenesis to achieve greater thermotolerance; in vivo supplementation of compounds that reduce cellular stress (e.g., orally, or by intramuscular/intravenous administration); and in vitro supplementation of gametes/embryos (for use in reproductive biotechnologies) to decrease cellular stress. These strategies aim to reduce heat-induced fertility alterations, both systemically and directly in reproductive structures.

Given the serious risk that global warming poses due to the impact of heat on physiology, we urgently need more studies on the overall context of animal reproduction under HS. In addition, we require a specific focus on the impact of HS on reproductive processes, considering factors such as regions, production systems, species, breeds/strains, and particular genetic backgrounds. Therefore, whether the heating that planet Earth experiences will lead to disastrous effects on animal reproductive capacity or a more controlled, perhaps partially reversible, decrease in such capacity, could be influenced by the measures we plan now. These include efforts from society, governments, and veterinary professionals. Time is running out: the situation calls for immediate action.

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## Conflicts of interest

The authors have no conflicts of interest to declare.

## Author contributions

Conceptualization: HO Toledo-Alvarado, E Orozco-Lucero.

Writing-original draft: HO Toledo-Alvarado, E Orozco-Lucero.

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