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Editorial: Mammalian responses to climate change: From organisms to communities

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Editorial on the Research Topic
Mammalian responses to climate change: From organisms to communities

Mammals have displayed spectacular evolutionary success ever since an asteroid impact caused the Cretaceous-Tertiary extinction event ~66 million years ago, when the non-avian dinosaurs disappeared. Now another mass extinction event is underway because of another major planetary disturbance, but this time it is directly caused by just one over-achieving species among all those mammals: *Homo sapiens*.

A particularly powerful component of the Anthropocene extinction is global climate change, which, in concert with other elements of anthropogenic forcing, is driving the reorganization of biotic assemblages everywhere on the planet. Rising ambient temperature challenges the adaptive capacity of organisms and for terrestrial animals it can directly cause lethal hyperthermia or dehydration. More generally however, the indirect effects of climate change permeate all facets of the environment including habitat quality (food, water, refuge availability) and risks from predators, competitors, and pathogens (Figure 1). Chronic exposure to environmental conditions that exceed critical thresholds at critical times of year ultimately result in a convergence of sublethal fitness costs (Pattinson et al., 2022). Such costs could arise from disturbances to physiological processes and behavioral patterns, which become expressed at the population level as changes in vital rates and habitat occupancy. These in turn drive shifts in species ranges or even extinctions, with consequences at community and ecosystem levels.

For mammals, some excellent examples of the direct and indirect effects of climate change are presented in the series of papers in this Research Topic. Using a 19-year data set from Isle Royale National Park, Hoy et al. describe how warmer summers are associated with increased tick burdens carried by moose (*Alces alces*), which in turn incur increased predation by wolves (*Canis lupus*). They infer that warmer temperatures benefit tick populations and moose with heavier tick burdens are weaker and thus less successful in escaping from cursorial predators like wolves. Then, fear of wolves

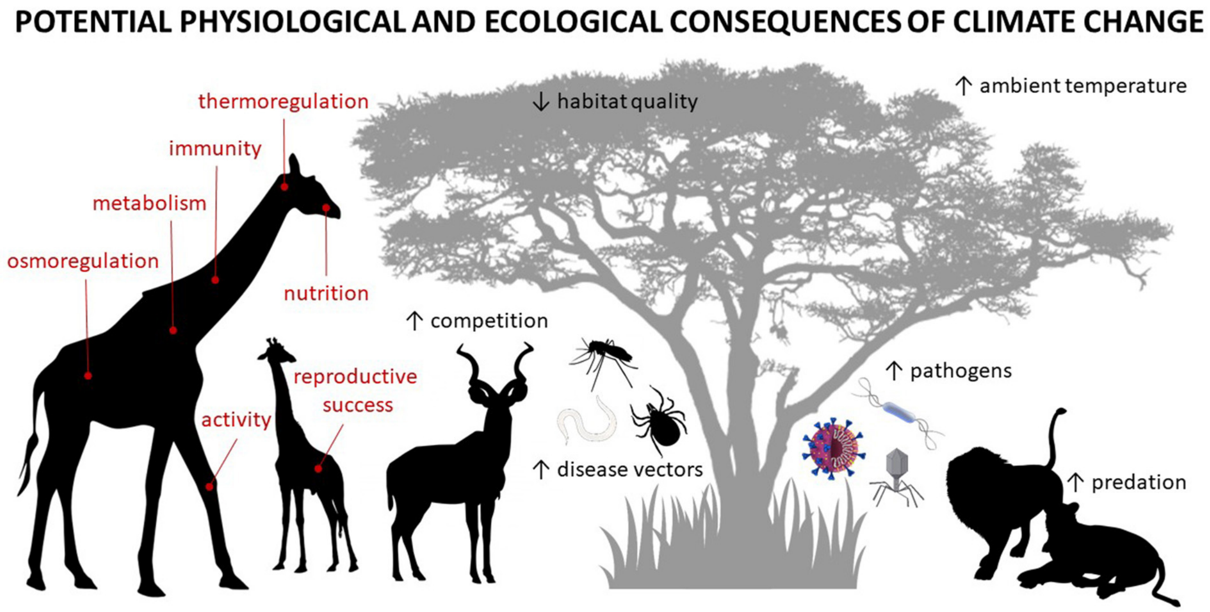

FIGURE 1
Global climate change interacts with multiple determinants of the local environment to which an organism is adapted, including ambient temperature, habitat quality (food, water, refuge), and challenges from predators, competitors, and pathogens. Persistence requires the negative fitness consequences of disturbed physiological and behavioral systems to be overcome through successful adaptations selected at a rate commensurate with the rate of climate change. The papers in this Research Topic explore some of those interactions and their implications.

could exacerbate the cycle by motivating moose to select habitats with lower predation risk but higher tick infestation. A similar but independent conclusion comes from the modeling exercise of Morin et al. who used data from large predators and their prey in an African savanna. Their models predict an increase in the vulnerability of prey to cursorial predators because of both reduced prey body condition and improved hunting success in habitats altered by aridification.

In addition to aridity, increasing ambient temperatures could further exacerbate poor body condition of herbivorous prey if food intake is reduced. Beale et al. document that increasing ambient temperatures reduce food intake of marsupial folivores, which seems to be linked to suppressed hepatic metabolism and detoxification capacity for plant secondary metabolites in their diet. Avoidance of heat stress can involve shifting patterns of activity and/or habitat use, but Reher et al. show that intraspecific adaptive capacity is limited. They examined two populations of Malagasy bat (*Macronycteris commersoni*) that roost under different microclimatic conditions, one inside a hot and humid cave and the other under foliage in forest trees. By experimentally switching the microclimates of individuals, they discovered that physiological variation between populations does not translate to flexibility at the species level. Intraspecific variation in thermoregulation could derive from local adaptation selected in separate populations on time scales incompatible with the current rate of climate change.

The work described in this Research Topic provides lessons that can help improve our forecasts of the effects of climate change on mammals in general, and especially those already in decline. By way of illustration (Figure 1), we point to the giraffe (*Giraffa* spp.) populations of Africa, which have declined by almost 40% overall since the 1980s (O'Connor et al., 2019). Although the reduction in giraffe numbers is largely because of human overhunting and habitat loss, climate change is emerging as a strongly contributory factor, which might seem surprising. Being native to habitats ranging from the semideserts of the Sahel and Namib to the mesic woodlands of eastern and southern Africa, it might be assumed that giraffes are generalists and are thus able to adapt to climatic variation. That assumption is, however, misleading as Reher et al. warn us that local adaptations can develop over long periods across different climate envelopes. Indeed, a recent whole-genome analysis reveals the extent of genetic differentiation by defining no <4 extant species and seven subspecies within the *Giraffa* genus (Coimbra et al., 2021). Each population within each of those genetically distinct units faces its own specific set of challenges from climate change. Giraffes are forced to substantially reduce their feeding time on very hot days (du Toit and Yetman, 2005), and so the lesson from

Beale et al. is highly pertinent. Being folivores with diets rich in plant secondary compounds, the giraffe detoxification system is likely vulnerable to increased ambient temperatures. Furthermore, the separate studies of Morin et al. and Hoy et al. both warn of climate change having interacting effects through predators, habitats, and pathogens, which are again all exemplified by the case of giraffes. Giraffe skin disease (GSD) is emerging in areas where climatic conditions favor the insect vectors of the filarid nematodes that cause the disease (Han et al., 2022). In Tanzania, where giraffes are the preferred prey of lions and GSD is now prevalent in at least 85% of the population, disease severity appears to reduce the likelihood of a giraffe surviving a lion attack (Muneza et al., 2021).

This Research Topic reaffirms that global climate change is altering the specific climate envelopes to which local populations of mammalian species are adapted, and the rate of alteration exceeds the rate of adaptation. For conservation, the way forward is obviously extremely challenging but science can help. The effectiveness of practices such as assisted dispersal and rewilding depend on an understanding of the interactions among climatic and other environmental drivers, physiological, and behavioral responses at the organismal level, and their fitness consequences. Understanding those interactions and consequences, and the ways in which they propagate through population, community, and ecosystem levels, will advance with continued work of the type presented here.

Author contributions

JT, RH, and MD contributed equally to the conception, writing, and editing of this editorial piece. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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