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Commentary

The Final Ascent: from refuges to ruins in a warming world

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Abstract

Mountains exemplify how climate change transforms long-standing refuges into zones of loss. As species track suitable climates upslope, they confront absolute ecological limits. This commentary reflects on montane extinctions as a warning signal for broader planetary boundaries and the future of biodiversity in the Anthropocene.

Keywords

Anthropocene, biodiversity, climate change, mountain ecosystems, refugia

Ascent to Extinction

Mountain ecosystems have long functioned as both cradles and repositories of biodiversity. Their topographic complexity, climatic heterogeneity and relative isolation have promoted speciation and served as safe havens during glacial cycles (Steinbauer et al. 2016). The mountainous areas of Southwest Asia, including Iran, represented key refugia during the Last Glacial Maximum (LGM), sustaining populations that later diversified into a rich mosaic of endemic species (Noroozi et al. 2018). These montane endemics often occupy narrow ecological niches finely tuned to local climatic conditions, making them particularly sensitive to environmental changes (Rahbek et al. 2019).

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Today, these same mountains illustrate a profound paradox. As global temperatures rise, montane species increasingly shift their ranges upslope to track favourable climatic conditions (Pauli et al. 2012; Freeman et al. 2018). Yet, the vertical space that once offered refuge now imposes an absolute limit, the mountain summit. This process, often described as the escalator to extinction, transforms ancient centres of survival into zones of irreversible loss (Colwell et al. 2008). The populations that have been pushed back to these ecological upper limits on mountain peaks are threatened with local extinction and, ultimately, total extinction, due to the lack of other suitable habitats.

The story of montane endemics mirrors the broader trajectory of life on Earth in the Anthropocene. Just as mountain species are constrained by topography, humanity is confined by the ecological boundaries it has disrupted. The biosphere, our planetary refuge through countless epochs, now faces unprecedented pressures from climate change and biodiversity collapse (Pfenning-Butterworth et al. 2024). Although humanity itself is not physically limited by mountain topography, it nevertheless is confronted by analogous ecological boundaries, which also represent natural safeguards. The erosion of these natural safeguards threatens to turn Earth itself from a haven into a narrowing corridor of survival. Recognising mountains as both symbols and sentinels of change highlights the urgency of conservation and mitigation efforts. Protecting these ancient refuges is not only about preserving species, it is about preserving the conditions that have long made life possible. As the limits of ascent draw closer, both mountain endemics and humanity confront the same truth: survival depends on restoring the stability of our only refuge – Earth itself.

Conflicts of interest

The authors have declared that no competing interests exist.

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