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Niches beyond borders

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Analysis of distributional data for 25,000 species challenges the assumption that species are bound to the climatic conditions that they inhabit today, and argues that many species may be able to venture into unoccupied areas of their fundamental niche.

Understanding how species will respond to climate change is vital for anticipating the implications of biodiversity change on economics, geopolitics and health. But how accurately can we predict future species distributions? One might argue that our predictive ability is only as robust as our capacity to accurately quantify species' niches. Most projections of species responses to climate change are based on correlative niche-based models, calibrated with spatial datasets of species occurrences and climate for the past few decades. Such models rely on their ability to estimate accurately the niche of species. However, models informed with just a single, recent time period may consider only part of the environmental conditions over which a species could occur, and truncate portions of species' fundamental climatic niches[1–3]. If so, extinction-risk estimates based on these truncated niches may be biased[4]. Writing in *Nature Ecology & Evolution*, Chevalier et al.[5] explore the potential for niche expansions across terrestrial and marine environments. Their findings suggest a more optimistic outlook on biodiversity resilience in the face of climate change than has typically been presented.

The authors introduce the concept of niche contiguity, which is the proportion of the ecological niche's perimeter that is adjacent to the current climatic boundaries. Chevalier et al. propose that parts of a species' fundamental niche — the suitable conditions that it could inhabit — may remain 'hidden' owing to the current climatic conditions available on the planet. As the climate changes, these hidden niches — akin to ghosts of the past — could become accessible and offer species previously available climatic realms to colonize. By linking distribution records and climatic conditions for 25,000 plant and animal species across terrestrial and marine systems for assessing the magnitude of niche contiguity, the authors find that about 49% of the species analysed show niche contiguity and a substantial portion (86%) of species with niche contiguity could experience future niche expansion beyond current climatic limits.

The concept of niche contiguity offers a fresh view through which to view potential species distributions in a changing climate, but the question arises of whether there is empirical evidence in support of niche shifts over time and during periods of climate change. Two global natural experiments may help us to shed some light on this question. The responses of species to abrupt changes in climatic conditions across the late Pleistocene is one of them[6,7]. Research that links fossil distributions with palaeoclimatic data over the past 50,000 years has revealed that across North America and Europe, most plant taxa occupied similar (though not identical) climatic niches through various climate change events[8]. Notably, about 30% of all plant taxa exhibited shifts in their realized climatic niches over time. Evidence for mammals in North America shows that they are now living in different climates than they did before major human expansions, which means that the distributions of modern mammals do not accurately reflect the range of climatological conditions where the species can live[9]. Another natural experiment involves the niche dynamics of invasive species. Recent evidence indicates that although most invasive species maintain their climatic niches, substantial variations exist among different taxa. Notably, about 15% of invasive plant species have adapted to climatic conditions that are outside of their current native ranges[10]. Consequently, the potential for niche shifts in certain taxa and regions appears plausible.

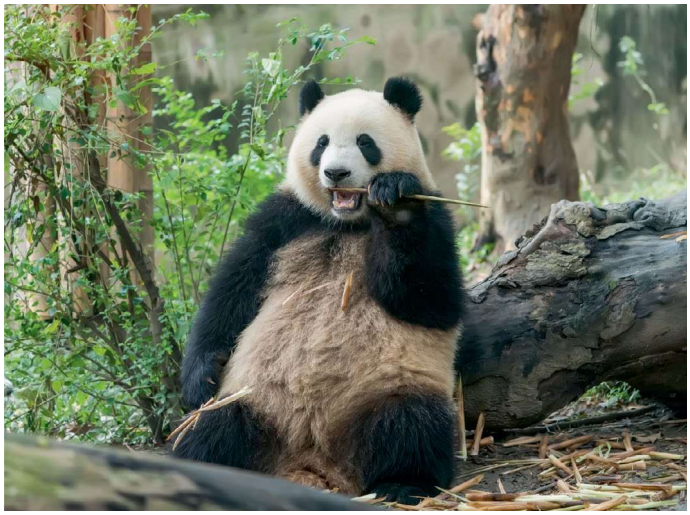

Fig. 1 | Niche shifts. During the early-to-middle Holocene, the giant panda occupied a niche that was considerably larger niche than its current niche, which has shrunk to three times smaller following a reduction in their geographical range alongside a substantial dietary shift towards almost exclusively consuming bamboo[13–16].

Nevertheless, our understanding of species niches remains imperfect. Measuring the ecological and climatic conditions that allow a species to maintain viable populations is still a bumpy road. For example, it is possible that species today are reoccupying ecosystems they once inhabited, before they were excluded by humans (Fig. 1). There is evidence across different ecosystems of species being found in places they were not expected to be, and that they have expanded their ranges and recolonized ecosystems that were previously assumed to be outside of their niche breadth[11]. The documented recolonization of ecosystems by species such as sea otters and alligators — which were previously thought to inhabit narrower ecological realms — underscores the existence of 'ghost niches'. It also challenges ecological paradigms about niche

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plasticity and the ability of correlative niche models to predict future biodiversity dynamics.

A critical consideration to reflect upon is that species themselves do not respond to climate change, but individuals within populations do. In this context, the presence of niche contiguity does not inherently guarantee that niche expansion will occur. It is plausible that past 'ghost' climatic niches were occupied by populations that became locally adapted to specific climatic conditions, but that no longer exist. The genotypes of these populations (the haplotypes) represented adaptive responses of the species that may no longer exist within the species' current genetic variability. Similarly, extant populations today are the result of millennial-to-centennial-scale adaptation dynamics. Consequently, there is a tangible possibility that the existing populations of a species might not adapt swiftly enough under new selective pressures to resemble those populations from the past. This could prevent them from expanding into regions beyond the niche space that they occupy today.

Thus, although Chevalier and colleagues' findings are thorough and exciting, a nuanced consideration of their generality is warranted. The results also provoke a call for developing and improving methods and data for better capturing the niche of species. Alongside the valuable concept of niche contiguity, integrating past and present distributions with process-based models or the exploration of the genetic basis of adaptation may also enhance our understanding of the ecological conditions under which species can persist[12].

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Competing interests

The authors declare no competing interests.