CLIMATE CHANGE ECOLOGY

Decoupled land–sea biodiversity trends

A global analysis of biodiversity time series across temperate zones shows contrasting fingerprints of contemporary climate warming on species assemblages over land and sea. A net increase in the number of species is evident in the warmest temperate oceans but no systematic biodiversity trend is detected in the terrestrial realm.

Lise Comte and Jonathan Lenoir

As climate change unfolds, rapid changes in population dynamics and species distributions have been documented from polar to tropical regions[1,2]. These changes are thought to result from the sensitivity of organisms to climate exposure and from intrinsic characteristics associated with the capacity to adapt to these changes in the environment[3]. It takes substantial efforts to understand the redistribution of a single species, so anticipating climate-induced effects on species assemblages is a challenging task. A key question is how predictable is the climate-induced redistribution of biodiversity on Earth. Writing in *Nature Ecology & Evolution*, Antão and collaborators[4] provide a detailed analysis of the extent of climate effects on biodiversity in both marine and terrestrial species assemblages, using the largest database of biodiversity time series available to date, which spans plant, invertebrate and vertebrate groups (bioTIME[5]).

Antão et al. quantified two aspects of changes in species assemblages, namely trends in species richness and total community abundance. They then related these biodiversity trends to mean temperature trends observed over the same period of time, ranging from a few years to 97 years for the longest time series (Fig. 1). The authors hypothesized that warm temperate regions that border the species-rich tropics would experience the greatest influx of climate migrants, resulting from the convergence of higher temperature sensitivity of tropical species and tropical areas being hotspots of biodiversity. They also predicted that the higher sensitivities to warming and faster rates of colonization in the marine realm would lead to a tighter coupling between temperature and biodiversity changes at sea than on land.

In accordance with their expectations, Antão et al. find evidence of a global fingerprint of climate warming on marine species assemblages but no systematic temperature-induced biodiversity reshuffling on land, despite the rate of temperature increases being nearly two-times faster on land than in the ocean. Importantly, the authors show that the number of species has increased in species assemblages occurring in the warmest temperate oceans, following rises in sea surface temperature, but that the same amount of warming resulted in net biodiversity losses in the coldest temperate oceans. While the results suggest a lower degree of predictability of climate-induced changes in the terrestrial realm, they also indicate that even in the ocean, climate exposure alone is not sufficient to explain the redistribution of biodiversity.

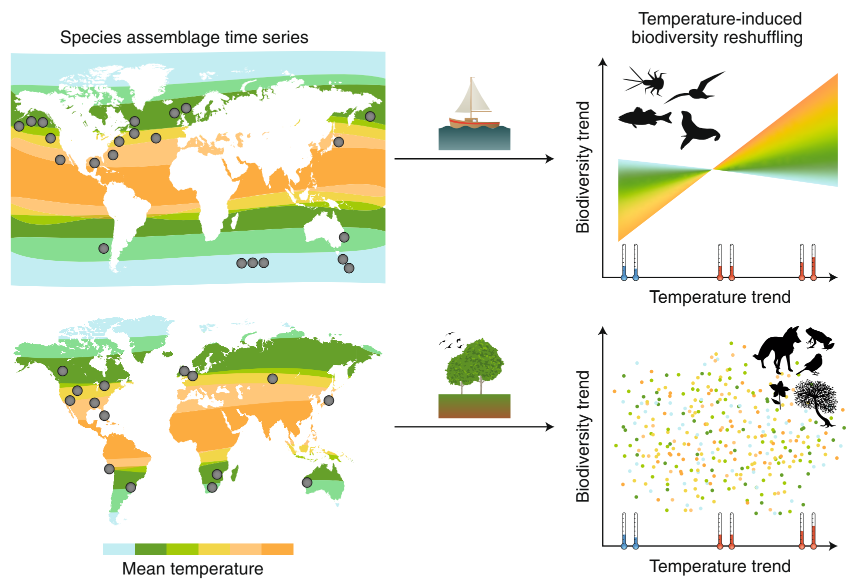

Fig. 1 | Climate-induced effects on species assemblages differ between marine and terrestrial realms. Antão and colleagues[4] relate biodiversity and warming trends quantified for 21,500 communities across the temperature gradient of the temperate zone at sea (top) and on land (bottom). They show that over the last decades the number of species has increased in the warmest temperate oceans where temperatures have also increased the most, suggesting an influx of climate migrants from the neighbouring tropical waters. They also find that species richness has decreased in the coldest temperate oceans subjected to the same rate of warming. In contrast, no clear association was found in the terrestrial realm, indicating no systematic temperature-induced biodiversity reshuffling.

The real-world patterns revealed by Antão et al. open a new line of inquiry about how the mechanisms that promote temperature-induced biodiversity reshuffling may differ between land and sea. Given that terrestrial and marine organisms occur, and have evolved, in fundamentally dissimilar environments, the fact that the consequences of climate change on biodiversity differ in important ways as well is not entirely surprising. Physiological experiments suggest that the spatial scale of climate change responses may differ radically between the marine and terrestrial realms[6]: large-scale species range shifts may be the dominant response at sea, whereas local thermal refugia may be key for terrestrial species to adapt to the rapid pace of contemporary climate change. To further our understanding of the mechanisms underlying biodiversity redistribution on land, we must thus study them at the appropriate scale[7]. In this regard, recent developments in remote-sensing technology may provide new opportunities to accurately map microclimates and associated biological responses to climate change[8]. Understanding how these pieces connect across scales is an ongoing but fascinating challenge facing ecologists.

Interestingly, Antão et al. show that in the ocean the increase in the number of species in the most rapidly warming areas of the temperate zone results from species gains currently outpacing species losses. This is consistent with climate-induced range expansions being five-times faster than range extirpations in the ocean[1]. However, the concomitant decrease in total abundance observed across the warmest temperate oceans raises questions about the permanence of the reported biodiversity increase at these latitudes. Should one expect delayed extinction of the most sensitive species within these assemblages to offset or even outpace species gains in the future? As climate warms, direct risk of thermal thresholds being exceeded (when temperatures rise above thermal tolerance) is increasingly likely to challenge the persistence of organisms in the warmer parts of their distribution range. Indirect biotic interactions in which climate migrants exert new competitive or predation pressures on the recipient assemblages could also accelerate local extinction events. These transient dynamics in a time of rapid environmental change are poorly understood, and deserve formal analysis and experiment.

Even though Antão et al. do not directly address the question of how intrinsic species characteristics mediate species assemblage responses, they show that the initial temperature regime experienced by communities is key to understanding the redistribution of biodiversity, at least in the ocean. A clear next step is thus to get a better mechanistic understanding of the reported patterns. For instance, is the increase in species richness in the biogeographic transition zones bordering the tropics associated with an increased representation of warm-water species over time — a process referred to as the 'tropicalization' of species assemblages? Conversely, can species losses in the coldest ocean waters of the temperate zone be explained by the interplay with human activities such as marine fishery exploitation[9]? The fairly consistent responses documented across taxonomic groups also calls for more detailed analysis of how different thermal physiologies (cold- versus warm-blooded) and life-history strategies (slow versus fast life cycle) may be sensitive, and respond to climate change. Although the questions raised by the findings of Antão et al. cannot all be resolved at once, the study should inspire future research on the contrasting biodiversity responses to climate change between marine and terrestrial realms. ❐

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Competing interests

The authors declare no competing interests.