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commentary

Studying the effects of climatic gradients within anthropogenic environments improves biogeographical inferences

Due in large part to global climate change (Karl and Trenberth 2003), there is increasing interest among biogeographers in exploring and understanding how species' distributions are delineated by climatic conditions. Over the past several decades, species have been responding to increasing temperatures by shifting their distributions to cooler climes at higher latitudes or elevations (Parmesan 2006). As a result, research efforts have increasingly focused on assessing how climate defines species' current and future distributional limits along elevational and latitudinal gradients (Thomas 2010).

A key consideration when studying elevational and latitudinal gradients is that temperature changes in a very different spatial fashion along each gradient. The tropospheric lapse-rate, which is an estimate of the relationship between temperature and elevation within the troposphere, averages $6.2\text{ }^{\circ}\text{C km}^{-1}$ over the continents, with a range of 4.5 to $6.5\text{ }^{\circ}\text{C km}^{-1}$ from the polar latitudes to the equator, respectively (Mokhov and Akperov 2006). In contrast, the relationship between temperature and latitude is nearly uniform in the tropics, and declines roughly $0.007\text{ }^{\circ}\text{C km}^{-1}$ on average north of the Tropic of Cancer and $0.005\text{ }^{\circ}\text{C km}^{-1}$ on average south of the Tropic of Capricorn (F.A. La Sorte, unpublished). One would expect these unique spatial relationships with temperature to result in equally unique associations with species' distributional limits along these gradients. However, it is often assumed that elevational and latitudinal gradients function in a similar manner in defining distributional limits.

When considering how dispersal processes are likely to differ along these gradients, one prediction is that the spatially compressed elevational gradient should result in species' distributions extending further into colder environments through more frequent and successful dispersal events (Halbritter et al. 2013). A primary challenge in testing this prediction is that experimentation is not always feasible along these gradients, and es-

pecially latitudinal gradients, limiting the ability of investigators to control for the influence of non-climatic factors. Climate acts in combination with an array of abiotic and biotic factors in determining species' distributional limits (Sexton et al. 2009), and isolating the effect of climate is not always a simple task. For example, the role of climate in defining species' latitudinal responses to global warming may be surpassed by more intensive local or regional processes, such as land-use change or management activities (La Sorte and Thompson 2007). When these processes cannot be identified and moderated, an alternative is to incorporate influential local and regional factors directly into the study design. A recent study in *Global Ecology and Biogeography* used such an approach to assess the comparability of species' distributions along elevational and latitudinal gradients.

Halbritter et al. (2013) documented the distribution of 155 common ruderal herbs along an elevational gradient in the Swiss Alps and along a latitudinal gradient in Northern Europe. The two gradients vary in distance but both cover a similar range of temperatures. To minimize the effect of non-climatic factors, plant surveys were conducted within disturbed habitats along roadsides and in human settlements, and species were selected that were strong dispersers and geographically abundant. By incorporating an anthropogenic perspective into the study design, Halbritter et al. (2013) were able to sample plant communities at sites containing similar physical environments, thus providing inferences focused more exclusively on the effects of external climatic processes. Moreover, because these anthropogenic environments were characterized by high disturbance frequencies and high levels of biotic interchange, distributions and climatic associations of these highly dispersive, ruderal taxa were likely to be estimated in a more accurate fashion along both gradients.

Halbritter et al. (2013) found that tempera-

ture limits and patterns of abundance differed between elevational and latitudinal gradients. In agreement with expectations, species were associated with colder temperatures and patterns of abundance decreased more gradually along the elevational gradient. There are several possible explanations for these findings. Based on the controls included in the study design, these findings support the conclusion that, as emphasized in other studies (Bertrand et al. 2011), the compressed elevational gradient may allow plant species to more effectively track inter-annual changes in climate, and in some cases to exceed their climatic limits through rescue effects or other source-sink dynamics (Brown and Kodric-Brown 1977). These findings support the conclusion that assuming similar processes in defining distributional limits for both gradients is not always tenable, and combining both gradients into one metric based on relatively coarsely defined climatic data (e.g., Loarie et al. 2009) may mask species' potential to respond geographically to climate change. This may be of particular relevance in topographically complex landscapes where geographical responses along spatially compressed elevational gradients may take precedence over latitudinal gradients.

The unique approach employed by Halbritter et al. (2013) that directly incorporates anthropogenic environments into the study design to minimize the confounding effects of non-climatic processes sets the stage for future work exploring other regions and taxa, which would clarify the broader relevance of the study's findings. The addition of experimental approaches to the current study design would also provide opportunities for mechanistic insights; however, at this time, this may only be feasible for elevational gradients (Sundqvist et al. 2013). In total, as the drivers of global change continue to develop, biogeographers are increasingly studying systems that have been altered through human activities (La Sorte 2006). The consequences, however, are not always detrimental, at least from a scientific perspective. Through intelligent study design, alternative observational perspectives can be created, which may lead to refined scientific inferences. The products of these efforts can improve bio-

geographical knowledge, which may lead to an improved understanding of the current and future ecological consequences of global environmental change.

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