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Climate-driven range dynamics and potential current disequilibrium in Alpine vegetation

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Abstract

Recent climate change is shifting species' elevational ranges. Yet, most research effort has concentrated on the uppermost occurrences of species and little is known about changes to species' rear edges, optima and abundances. However, only the simultaneous consideration of these range attributes allows for assessing the fate of mountain plants under climate change. Instead of using exactly localizable plots, we re-surveyed over 1500 semi-permanent historical vegetation relevés spread over the European Alps to overcome these shortages. Based on this dataset we evaluated recent range dynamics along the elevational gradient, traits associated with particular responses to climate, and the emergence of dispersal limited distribution patterns and extinction debts.

Keywords

mountain, biodiversity, climate change, range shift, plants, re-survey

Summary

As climate warms plant species are shifting their elevational ranges and climatic trends appear the most plausible drivers of these dynamics in many cases (Chen et al. 2011). Although expectations and observations match by trend our current knowledge about the impacts of a warming climate on species distributions and biodiversity patterns is still limited in many respects. However, understanding these processes is vital for accurate predictions of changes in biodiversity patterns and effective adaptions of conservation efforts in protected areas.

The current knowledge suggests that species have responded idiosyncratically to climatic trends (Williams & Jackson 2007). The velocity of elevational range shifts vary considerably, with variation within taxonomic groups being even more pronounced than variation among them (Chen et al. 2011): While some species seem to be able to follow climatic changes without delay, many others lag behind climatic shifts more or less pronouncedly, entailing a disequilibrium between climatic conditions and current distributions. The causes of this variation are barely understood. On theoretical grounds, species should track changing climates the faster the higher their dispersal capacities, and the wider their ecological niches (Angert et al. 2011). Indeed, some recent studies found support for this hypothesis (Angert et al. 2011) but the relationships remained weak throughout and trait-based predictions about species-specific threats under climate change are thus still hardly possible.

Furthermore, there is hardly any report of recent range dynamics that does not document unexpected downward displacement of at least some species' ranges (Lenoir et al. 2010, Chen et al. 2011). In some cases, these 'surprises' seem to be driven by the intervening effects of other climatic factors like precipitation changes (Crimmins et al. 2011), by land use dependent habitat modification (Hättenschwiler & Körner 1995) or may involve changing biotic interactions (Brooker 2006). Mostly, however, the reason(s) remain contentious.

Apart from interspecific variation, range attributes of a single species may respond inconsistently to climate. As yet, most studies have concentrated on leading edge shifts despite the obvious importance of contracting rear edges in a conservation context (Hampe & Petit 2005). In particular, there are few studies that have considered both range limits simultaneously and still less that also included shifts of range optima and changes in abundance. For plants, rear edge dynamics are supposedly associated with longevity and persistence ability which might enable remnant populations to survive at sites no longer climatically suitable for decades (Eriksson 2000). In addition, climatic gradients are steep in alpine terrain and, hence, geographical distances among climatically distinct habitats small, fostering mountain plants in tracking climatic changes relatively easy (Engler et al. 2011). As a consequence, leading edges are thought to shift faster than rear edges (Hitch & Leberg 2007, Chen et al. 2009) but the generality of this pattern remains to be tested. As a corollary, species richness of local plant communities should tend to increase because the colonisation by new species occurs faster than the extinction of resident plants. Such a transient increase has been reported by re-surveys in temperate mountain ranges during the recent decades (Pauli et al. 2012). However, in the course of an apparently irreversible climatic trend, the involved remnant dynamics imply the build-up of an extinction debt (Jackson & Sax 2010) that will have to be paid off after a more or less extended delay. Indeed, an accumulating extinction debt has been predicted to arise in alpine plant communities (Dullinger et al. 2012).

With respect to plants in alpine terrain, progress in studying these issues is constrained by the limited focus of most empirical work conducted so far: research interest has yet mostly been concentrated on changes in species composition of mountain top plant assemblages (e.g. PAULI et al. 2012). This restricted focus follows from the prevailing research strategy of re-surveying exactly localizable historical plots which are few, geographically clustered and topographically biased. More importantly, the focus on mountain tops does not allow for assessing whole range dynamics or for getting indications of possible disequilibria and extinction debts. To overcome these limitations we re-located and subsequently re-surveyed over 1500 historical vegetation relevés spread over the European Alps based on their topographic information. The data was used to evaluate species' range dynamics at rear edges, optima, leading edges and changes in abundance during the last decades, the traits potentially associated with responses to climate, and the emergence of dispersal limited distribution patterns and extinction debts.

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