Reply to Le Roux *et al.* 2020: Plant diversity and climate change in The Anthropocene

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eTOC blurb

Replying to Le Roux *et al.* (this issue), Suggitt *et al.* find the effect of climate change on local species richness to be robust to the inclusion of alternative drivers of species turnover. Climate change appears to be increasing local richness at some sites, although not all effects of climate change on plant diversity are positive.

Main text

The Earth's climate has warmed by 1°C since pre-industrial times, driven by levels of atmospheric greenhouse gases not seen for at least 800,000 years [1]. Climate change impacts now extend to 82% of ecological processes across the marine, freshwater and terrestrial realms [2], and as many as one in six species could face extinction should emissions continue unabated (i.e., under IPCC RCP 8.5) [3]. These findings represent strong motivation for avoiding 'dangerous' climate change, which could be inevitable within one or a few decades [1]. They also represent an opportunity to examine the relationship that exists between the Earth's climate and its biota. This relationship is fundamental to understanding the parameters under which most ecological patterns and processes occur, at almost any scale [4].

The number of species observed at a local level (alpha diversity or species richness) is one important parameter, affecting local interactions and potentially influencing ecosystem resilience and the provision of ecosystem services. Despite global-scale declines in diversity, recent meta-analyses [5-6] have concluded that diversity at the local level has, on balance, remained about the same (increasing in some places and declining in others). If we are to understand this apparent disparity, it is vital to identify if, how, why and where biological turnover leads to increases or losses of species richness. We already know that local communities are receiving new arrivals as well as losing former residents [7], but the question of what could be driving the net balance of arrivals and departures remains largely unresolved. In a study published last year in *Current Biology* [8], we used one of these meta-analytic datasets [5] to test for effects of climate, and of climate change, on plant diversity changes around the world. We found that local diversity has tended to increase in cool regions where the climate has changed the most, particularly where the precipitation regime has been altered. We suggested that the net 'perturbation' effect of climate change could have increased local species richness, at least temporarily, as species arrived quicker than resident species died out.

Le Roux *et al.* [9] raise three concerns with how the conclusions from our paper might be interpreted. Their first concern is (a) whether the provenance of the underlying diversity data allow (b) climate change effects to be separated from other putative effects. In terms of provenance (a), our primary statistical conclusion was that cool regions with the greatest precipitation changes had experienced increased local plant species richness, for which the underlying data are robust. Of course, increased spatial coverage of data from the global south (South America, Africa, Australasia) is a matter of urgency, particularly given that extinction risk is most pronounced in these regions [3]. In terms of distinguishing between potential drivers (b), we identified effects of climate and climate change even after controlling for other, author-identified drivers of diversity change; these effects are observable in both the raw data (Figure 2, [8]) and the predictions of the statistical models (Figure 3, [8]). Their explanatory power may not be as great as the combined effect of all other drivers of diversity change, but climate nevertheless explained 12-30% of the variation ascribed to these drivers (depending on model formulation). To us, a finding that one factor could explain as much as 30% of the combined effect of ten other drivers is remarkable enough.

Le Roux *et al.*'s [9] second concern is that the new arrivals may be "*invasive or cosmopolitan weeds*" and impact adversely upon resident species. Le Roux *et al.* [9] report that some 137 of the 518 new arrivals identified in the original studies [6] have been reported as alien 'elsewhere in the world'. At the site level (which we are analysing), this statistic conflagrates native species (that have one or more populations elsewhere in the world) colonising sites in their 'homeland' with the arrival of non-native species. Using the data of Le Roux *et al.*, we can see that only 44 (or 8.5%) new arrivals were species alien to the region of the study site. Thus, the overwhelming majority (91.5%) of new arrivals were species already native to the region; consistent with other evidence that the re-organisation of plant communities can often be driven more by changes in the relative abundances and distributions of native species than by non-native arrivals [10]. The footprints of non-native plants are not as 'staggering' as Le Roux *et al*. suggest, at the spatial scales and regions considered here. Whatever the mode of transport and distance travelled, new arrivals will certainly play a substantial role in the reorganisation of plant communities in response to climate change, but in all cases climate and climate change will affect the ability of the new arrivals to establish and/or compete with the resident flora [4]. We need a renewed focus on identifying the impacts of species arriving in local communities, regardless of their provenance.

Le Roux *et al.*'s [9] third concern is that "*a false sense of security vis-a-vis climate change"* could arise unless a "*deeper consideration"* of climate change impacts is sought. We stated that the changes we reported referred to local richness, identified that any increases could be transient, and emphasised the changes in relatively cool parts of the world, for which the data and changes are clear. We made it explicit that: "*It is important not to confuse this positive effect of climate change on local-scale species richness with its heightening of global extinction risk for a substantial portion of the species on our planet*". Our data-driven hypothesis is that the perturbation to local plant communities associated with absolute (positive or negative) precipitation changes in relatively cold parts of the world has contributed to increases in local species richness. It requires further testing. We maintain that, whilst it is critical to understand where, when and why biodiversity is declining, it is also important to recognise situations under which diversity is increasing (at any scale) in the Anthropocene epoch.

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