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Understanding ecosystems of the future will require more than realistic climate change experiments – a response to Korell et al.

Critical examination of the approaches ecologists employ to understand complex ecological systems is integral to advancing our science. Recently, Korell et al. (2019) argued that climate change experiments would yield more relevant information on future functioning of ecosystems if the treatments imposed more closely reflected model-projected climate scenarios. To reach this conclusion, the authors evaluated 76 studies and found that changes in (manipulated) precipitation and air temperature generally did not match site-specific changes projected by Global Circulation Models.

The picture painted by Korell and co-authors, that only experiments mimicking realistic climate change forecasts are truly helpful in determining the fate of plant communities and ecosystems, is too gloomy. A more comprehensive study by Song et al. (2019) found that across 1,119 experiments, the majority of mid-latitude warming experiments were actually within the projected warming range. For precipitation, imposed experimental changes do generally surpass mean rates of projected changes, as suggested by Korell et al. In part, this reflects extreme events research often focused on short-term variability, i.e. droughts and heavy precipitation, events which are realistic but cannot be readily extracted from projections of mean precipitation (Field et al. 2012). These extremes can affect community structure and ecosystem functioning more than average changes (Smith 2011), which makes experiments on short-term variability highly pertinent.

But a broader question remains: are experiments that aim to mimic realistic climate change scenarios the best avenue to advance understanding and predictions? We disagree with Korell et al. in this regard. First, while there is value to experiments that apply specific future scenarios - how does one select the most realistic among a multitude of possible (and continually updated) scenarios? Korell et al. illustrate this problem in Fig. 1c and d, where depending on the RCP scenario, warming in the majority of experiments is either lower or higher than projections. Secondly, the goal of most manipulation experiments is not direct extrapolation of the study's findings, but to improve mechanistic understanding and the representation of biological processes in models, that in turn can predict outcomes under a range of potential future climates. Improving process understanding by focusing on continuous response surfaces rather than specific climate scenarios reduces context-dependency and allows extrapolation beyond the specifics of individual studies (Kreyling et al. 2018).

We believe that given the complexities, uncertainties and unknowns of climate change, we need a diverse portfolio of approaches. Conducting a wide range of experiments *is exactly what we should be doing*, particularly those that 1) push systems beyond historical and forecast extremes (Kayler et al. 2015), 2) manipulate multiple environmental drivers in factorial designs, 3) are designed to detect non-linearities, slow responses and legacy effects (Estiarte et al. 2016), as well as those that 4) can directly test model forecasts. The analyses of Korell et al. (2019) and Song et al. (2019) highlight this diversity of approaches in the existing literature. To understand ecosystems of the future, we need to embrace a wide array of experimental designs, including those that go beyond imposing the elusive realism of climate change scenarios.

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