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TECHNICAL COMMENT

Moving beyond methods: the need for a diverse programme in climate change research

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Abstract

Understanding effects of climate change on ecosystems will require a diverse range of approaches. We proposed using downscaled climate models to generate realistic weather scenarios as experimental treatments. Kreyling *et al.* propose a gradient approach to determine the shape of response functions. These approaches are different, but highly complementary.

Keywords

climate change, community ecology, downscaled climate models, experimental treatments, weather scenarios.

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Kreyling *et al.* (2013) make some important points in their response to our study (Thompson *et al.* 2013). We are in agreement that 'next generation' climate change experiments need to incorporate extremes and changes in variability. The ways in which this could be carried out are many. Our proposal was to use downscaled global circulation models (GCMs) to generate realistic weather scenarios, which can then be used as experimental treatments. This requires decisions to be made about which GCMs are used and under which emissions scenarios. Ensemble approaches are possible, but require careful design and the use of specific statistical tools to make experimental designs tractable (Lynch *et al.* 2001; Beringer *et al.* 2002). We suggest that in the immediate term it is entirely reasonable to concentrate on a single emissions scenario and that initial studies which use two different GCMs (to assess sensitivities to different GCM outputs) are both tractable and valuable.

Kreyling *et al.* (2013) propose a rather different approach. They suggest a regression/gradient design incorporating differences in means, variability and extremes. This would be a challenging but fascinating study, and potentially inform process-based model development. If treated from the viewpoint of studying the response curves of individual taxa to combined sets of conditions, it could go a long way towards understanding the mechanisms that underpin community-level responses to changes in thermal conditions. Importantly a gradient type approach would generate response curves which are amenable to scaling up and could potentially identify thresholds and tipping points.

The disadvantage of such an approach is that it takes a strictly mathematical approach to combinations of means, variability and extremes, and may generate combinations of conditions which are highly unlikely in the real world. It is also most tractable when considering single variables such as precipitation (e.g. Beier *et al.* 2012). Considering multiple aspects of weather (e.g. temperature, precipitation, cloud cover) as multiple interacting drivers in a gradient study that also considers treatment differences in means, variability and extremes would be logistically challenging (but by no means impossible). One of the strengths of our approach is that it creates realistic weather scenarios, based on non-random interactions between weather variables. For example in south-eastern Australia, GCMs predict increases in numbers of consecutive 40 degree Celsius days, combined with an increase in cloud cover and increased frequency of extreme summer rainfall events (CSIRO 2010). Using the weather scenario approach allows us to 'filter' all possible combinations of conditions to only test ones that are considered likely under climate change conditions. Our approach also develops patterns of extreme event occurrence which are reflective of the real world. For example, an extreme 40 degree Celsius day is much more likely if the previous day was also in excess of 40 degrees. The weather scenario approach generates patterns of occurrence of extreme events which are highly non-random and reflective of long-run characteristics of real weather. The disadvantage is that it does not generate gradients of response to all the interacting variables, making it more difficult to determine response curves of the sort that the gradient design would.

Understanding and predicting the effects of climate change on ecological assemblages is incredibly complex and challenging. It is important that we do not become distracted from this endeavour by differences in approach. Laboratory experiments, field studies, assays of individual physiology and measurements of ecosystem processes are all valuable and provide different and complementary lenses for understanding community responses to changing climate. Treatments in experiments need to incorporate realistic characteristics of future climates, but can be approached from a gradient perspective or a weather scenario perspective, each with their strengths and weaknesses. Both our study and Kreyling *et al.*

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(2013) show that there is a particular need to understand the effects of extreme conditions in the context of climate change across all areas of ecology, including genomics, physiology, population genetics, community ecology and ecosystem processes. The studies illustrate different but highly complementary approaches to understanding the complexities of community responses to climate change.

AUTHORSHIP

RT wrote the response in discussion and consultation with the other authors.

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