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Editorial overview: Global change biology: Linking pattern and process to prediction and policy.

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EDITORIAL OVERVIEW

Global Change Biology: Linking pattern and process to prediction and policy

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Human impacts on the environment are now so substantial that geologists have proposed a new epoch, the Anthropocene [1]. Insects drive ecological processes in most of the terrestrial and freshwater habitats on Earth. Because of their ecological, economic, and biodiversity importance, the responses of insects to changing climate are a critical component to predicting its consequences. However, the diversity of insects makes this prediction very challenging. In this section of *COIS*, we address the complex problems of why insects are affected by global change, and how we can predict and manage insect responses.

There is mounting evidence that insect populations and distributions are changing substantially, and that those changes can be attributed to climate change [2]. These changes are likely forced by a combination of factors, including temperature, which affects insects as ectotherms in terms of both survival (see also [3]) and phenology (see [4]). As well as direct effects on insects, climate change can also have indirect effects, and Verheggen *et al*. [5] outline the ways by which climate change may affect insect pheromonal communication. There are, of course, a number of other physiological parameters that may be affected by climate change and which are not captured here, ranging from pollutants and toxicants [6], to shifting water balance and availability [7], to changing winter conditions [8] or impacts on migratory routes or behaviour [9].

A particularly sobering thought is that many of these stressors are changing (and increasing) in combination as a consequence of global change, which means that an understanding of each stressor in isolation will not suffice. Kaunisto *et al*. ([10]; disclosure: one of us [BJS] is an author on this paper) consider how best to approach this issue. They focus primarily on how to determine if stressor interactions are generalizable (i.e. can be extrapolated beyond a specific study system) and predictable (i.e. can the interactions of novel stressor combinations be predicted *a priori* based on previous knowledge).

Predicting the impact of global change is essential for managing insect population responses – whether for medical, agricultural, forest, or conservation purposes. Most predictive approaches have their advantages and shortcomings [11, 12]; Lobo [13] examines the use of ecological niche models, and advocates placing renewed emphasis on presence (as opposed to absence) data; after all, absence of evidence is not evidence of absence, and beyond a few well-collected taxa and localities, we cannot be certain that the search effort justifies the certainty that some algorithms place on reports of 'absence'. By contrast, Maino and colleagues [14] advocate a mechanistic approach to predicting the effects of climate change. Mechanistic models are intrinsically appealing because, unlike ecological niche models which rely on the quality of data input to generate future distributions, mechanistic models are based on parameters from individual insects. Maino et al. [14] caution, however, that mechanistic models still require abundant and detailed input data, and cannot yet deal with the issues of multiple interacting stressors, which are implicit in ecological niche models. The macrophysiological approach [15], which derives predictions from global-scale patterns, is not addressed in this section, but we note that it risks assuming the weaknesses of both the niche models (which lack precision) and the mechanistic models (which are acutely dependent on input data quality). Perhaps the important take-home message for all of these approaches is that they are best assessed with a clear and open understanding of their limitations and advantages; we note that there is no particular reason that risks should be assessed based on only one approach.

Finally, global change is a large-scale problem, which means that even if we can predict the responses of insects to climate change, the ultimate responsibility for action lies at the level of policy development and implementation. Hellmann *et al.* [16] tackle the difficult (for ivory-tower-bound scientists) issue of how science can influence that policy. They point out that climate change will take place over a large geographic scale, requiring a shift toward collaborative and interdisciplinary approaches, and new, process-based, prediction frameworks that lead directly to management recommendations. In turn, managers need to be willing to make evidence-based modifications to management practices make use of this new information. Most critically, however, Hellmann et al. [16] emphasise that scientists must be willing to engage with stakeholders, society, and politicians, both to ensure that their conclusions (and their uncertainties) are adequately understood, and to help identify and advocate for evidence-based policies that will avoid exacerbating the impacts of climate change on insects, ecosystems, and society.

Our focus in assembling this issue has been on understanding the drivers of responses to climate change (we are, after all, both physiologists) and putting these mechanisms into the context of making recommendations. We hope that this collection of articles will spark ideas among the readers – not just for their own research, but for how their research can interface with the goals of researchers operating at different levels of organisation, geography, or political influence.

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