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RESPONSE

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Predict the effects of climate change by studying the effects of climate change

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Booth (2024) criticized our study for mentioning previous studies that tested climatic niche stability in introduced species (e.g., Petitpierre et al., 2012), but not including "forestry trials" (i.e., trees introduced for use in forestry). But how could we have included these trials? Booth (2024) stated that "almost no progress has been made with collating results from *ex situ* trials." Given the absence of a relevant database, it is unclear what Booth (2024) wanted us to do.

We made two major points relevant to Booth's (2024) critique. First, analyses of introduced species (including forestry trials) may be of limited value for predicting species' niche stability and future climate-change responses. For example, analyses of introduced reptiles and amphibians show a general relationship between climatic variables in species' native and introduced ranges (Wiens et al., 2019). Yet, many of these introduced species also underwent dramatic and rapid climatic niche shifts relative to their native ranges. These niche shifts were (on average) ~10 times faster than projected rates of climate change. Analyses of recent climate-related niche shifts in native plants and animals suggest that rates of niche change in introduced species might overestimate species' ability to respond to climate change in their native ranges (fig. 2; Wiens & Zelinka, 2024). One explanation for this pattern is that species' realized climatic niches are set by both biotic interactions and abiotic tolerances. Therefore, it may be problematic to ignore biotic interactions in species' native ranges when forecasting the impacts of climate change. Indeed, many recent climate-related declines are explained by changes in species interactions (e.g., Cahill et al., 2013; Ockendon et al., 2014). Two well-known examples of catastrophic climate-related changes in species interactions are coral bleaching and amphibian declines from chytrid fungus.

This brings us to our second point: given that species introductions may be problematic for studying climate change, then how should researchers predict the future effects of global warming? The answer is simple: they should predict the future effects of climate change by studying past effects. The impacts of recent climate change are already widespread, and have been for decades (Parmesan, 2006). These effects include warm-edge local extinctions that were observed in almost half of all species surveyed over time (Wiens, 2016). It is now possible to combine data on these local extinctions with data for the same species on niche shifts and dispersal, and then use these analyses to predict global patterns of climate-related extinction in the future (Román-Palacios & Wiens, 2020; Wiens & Zelinka, 2024). Much of these data on climate-related local extinctions were from surveys separated by many decades, a potentially important limiting factor. However, given accelerating climate change, it is now possible to observe ~70 years' worth of climate-related local extinction in only ~7 years (Holzmann et al., 2023).

In summary, we think that the future of climate-change research is not in studying introduced species (and forestry trials) to assess climatic niche stability for species-distribution modeling, but rather in studying the effects of climate change directly. This will require going beyond traditional species-distribution modeling.

AUTHOR CONTRIBUTIONS

John J. Wiens: Conceptualization; writing – original draft; writing – review and editing. **Joseph Zelinka:** Writing – review and editing.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analysed for the current article.

This article is a Response to the Letter by Booth, https://doi.org/10.1111/gcb.17243, which was related to the paper of John J. Wiens and Joseph Zelinka, https://doi.org/10.1111/gcb.17125.

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