Beyond global warming: Putting the “climate” back into “climate change ecology”☆

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ARTICLE INFO

Article history:
Received 22 March 2017
Received in revised form 22 March 2017
Accepted 22 March 2017
Available online xxxx

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Ecologists have a long-standing interest in understanding how Earth’s biota is affected by its abiotia. Even before Ecology was a named discipline, biologists such as Charles Darwin (1859) recognized that multiple abiotic factors were important for community dynamics and natural selection. In the early 20th century, forest ecologists explicitly incorporated the combined effects of temperature, precipitation, wind, light and moisture into their understanding of forest dynamics (Fricke, 1904; Pearson, 1920). Hutchinson (1944) identified temperature, light, and nutrients as important factors structuring phytoplankton communities, and Park (1954) famously demonstrated that temperature and humidity affected the outcome of intraspecific competition between flour beetles. Given this precedent, investigating multiple components of climate change should be a natural progression and primary research area in ecology. However, this does not seem to be the case.

Climate change is driven by elevated concentrations of greenhouse gases, in particular carbon dioxide. Thus, initial research on the impacts of climate change on ecological systems focused on the effects of CO₂ enrichment. Explicit investigation into the consequences of climate change for ecological communities accelerated in the mid-1990’s. Given that “climate change” was colloquially referred to as “global warming” at the time, it is not surprising that initial ecological studies emphasized the effects of temperature. However, the phrase is misleading, as some areas are cooling or not changing at all. Additionally, “global warming” fails to acknowledge the litany of other factors that are changing due to increasing concentrations of greenhouse gases.

Interestingly, the public may be embracing the more precise verbiage faster than the scientific community. The number of online searches for the phrase “global warming” decreased relative to online searches for the phrase “climate change” between 2004 and 2016 (Fig. 1; linear regression, slope = −0.22, p < 0.001; Data source: Google Trends, www.google.com/trends). Over the same time period, scientists did the opposite and used “global warming” at an increasing rate (Fig. 1; increasing ratio of published articles using “global warming” relative to “climate change” each year between 2004 and 2016; linear regression, slope = 0.094, p = 0.020; source: Scopus). Thus, while the general public has increasingly emphasized the multi-factor nature of climate change (at least in terms of internet queries), the scientific community has done the opposite and increasingly focused on a single factor, warming.

To illustrate this point, I searched the Scopus database for experimental studies on the effects of climate change on food webs (see Fig. 2 for search details). This search yielded 234 papers. I reviewed each paper and recorded which climate variables were studied (Appendix I). As predicted, temperature was by far the most studied climate variable and was investigated in 69% of papers. The next most
frequently studied climate variables were CO2 (16.2%; including pH and acidification studies), rain (15.8%; including drought and moisture studies), and nutrients (12.7%; including atmospheric deposition and eutrophication). Although I constrained my review to experimental studies, the pattern likely holds true for the broader literature: ecologists have studied the effects of temperature far more than other abiotic variables, and we know relatively little about how changes in those other variables will affect communities.

The presence of this bias in the literature motivated the special issue, *Diverse effects of climate change on ecological communities*. These papers review some of the most understudied aspects of climate change (Fig. 2), including ocean acidification (Ghedini and Connell 2017), phenology of sea ice (Post, 2017), changes in soil salinity (Harmon and Daigh, 2017), altered patterns of snow (Penczynowski et al., 2017) and reduced wind speeds, which are otherwise known as “global stilling” (Cherry and Barton, 2017). Additionally, Rosenblatt et al. (2017) model the effects of multiple changing variables (temperature, CO2, and water availability) on tri-trophic interactions. These articles not only synthesize the current literature, but also identify knowledge gaps and important future research directions with the attempt to further our understanding of the broad effects of climate change on communities. Although each review generally focuses on a single abiotic factor, a common theme that emerges throughout the special issue is that these factors are not independent. Thus, while it is important that research moves beyond “global warming” and investigates the effects of diverse abiotic factors, it is equally important that future work integrates the combined effects of multiple factors. After all, the objective of climate change research is not to understand the effects of individual components of climate, but instead understand the net effect of a changing climate.

**Appendix A. Supplementary data**

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.fooweb.2017.03.002.

**References**