Geographic differences in effects of experimental warming on ant species diversity and community composition

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Citation: Pelini, S. L., S. E. Diamond, L. M. Nichols, K. L. Stuble, A. M. Ellison, N. J. Sanders, R. R. Dunn, and N. J. Gotelli. 2014. Geographic differences in effects of experimental warming on ant species diversity and community composition. Ecosphere 5(10):125. http://dx.doi.org/10.1890/ES14-00143.1

Abstract. Ecological communities are being reshaped by climatic change. Losses and gains of species will alter community composition and diversity but these effects are likely to vary geographically and may be hard to predict from uncontrolled "natural experiments". In this study, we used open-top warming chambers to simulate a range of warming scenarios for ground-nesting ant communities at a northern (Harvard Forest, MA) and southern (Duke Forest, NC) study site in the eastern US. After 2.5 years of experimental warming, we found no significant effects of accumulated growing degree days or soil moisture on ant diversity or community composition at the northern site, but a decrease in asymptotic species richness and changes in community composition at the southern site. However, fewer than 10% of the species at either site responded significantly to the warming treatments. Our results contrast with those of a comparable natural experiment conducted along a nearby elevational gradient, in which species

co-occurring species (Tylianakis et al. 2008, Gilman et al. 2010, Singer and Parmesan 2010, Pelini et al. 2012). Populations and species occupying different locations may vary in their tolerances for abiotic changes (Deutsch et al. 2008, Tewksbury et al. 2008, Huey et al. 2009, Andrew et al. 2013, Kingsolver et al. 2013). Additionally, the indirect effects of climate change mediated by species interactions can strengthen or reverse the effects of abiotic change (Suttle et al. 2007, Rouifed et al. 2010, Pelini et al. 2011). As a consequence, it is difficult to predict how climatic change will shape the composition and diversity of local communities at small spatial scales.

However, at coarser grains of observation, such as latitudinal and elevational gradients, climatic differences may lead to predictable shifts in composition and diversity. In the simplest scenario, the poleward expansion of species geographic ranges may lead to an increase in diversity at higher latitudes, even though some species may disappear locally because they cannot tolerate warmer conditions. Net gains in species richness may arise because warming is unlikely to push many species above their thermal limits (Addo-Bediako et al. 2000, Deutsch et al. 2008, Tewksbury et al. 2008, Kingsolver et al. 2013). Conversely, at lower latitudes, sites should be more likely to lose species with increases in temperature because some species will exceed their critical thermal limits (Addo-Bediako et al. 2000, Deutsch et al. 2008, Tewksbury et al. 2008, Kingsolver et al. 2013) or experience too few days and hours within their range of optimal foraging temperatures.

Experiments that compare the effects of warming on communities near high- and low latitudinal range boundaries can test predictions about geographic patterns of warming effects on ecological communities. All other things being equal, "natural experiments" along elevational and latitudinal climate gradients can also predict which species can and will persist in particular climates (Ibanez et al. 2013). Differences in the response of species to natural thermal gradients and to controlled warming experiments might mond et al. 2012

matrix. In the second variation, we assumed there were detection errors and that some rare species were present that were not detected in any of the pitfall traps. For this analysis, we estimated the number of missing species with the Chao2 estimator. We added additional rows to represent these additional rare species in the analysis, and assigned relative abundances to be less than one half of the relative abundance of the rarest species in each community (see Gotelli et al. 2010 for details).

To determine if closely related speciesend

decreased in incidence,
whereas

southern and northern sites, respectively. Approximately 7% of the species were shared by all three sites; 30% were found only at the southern site, 19% only in the Great Smoky Mountains, and 11%

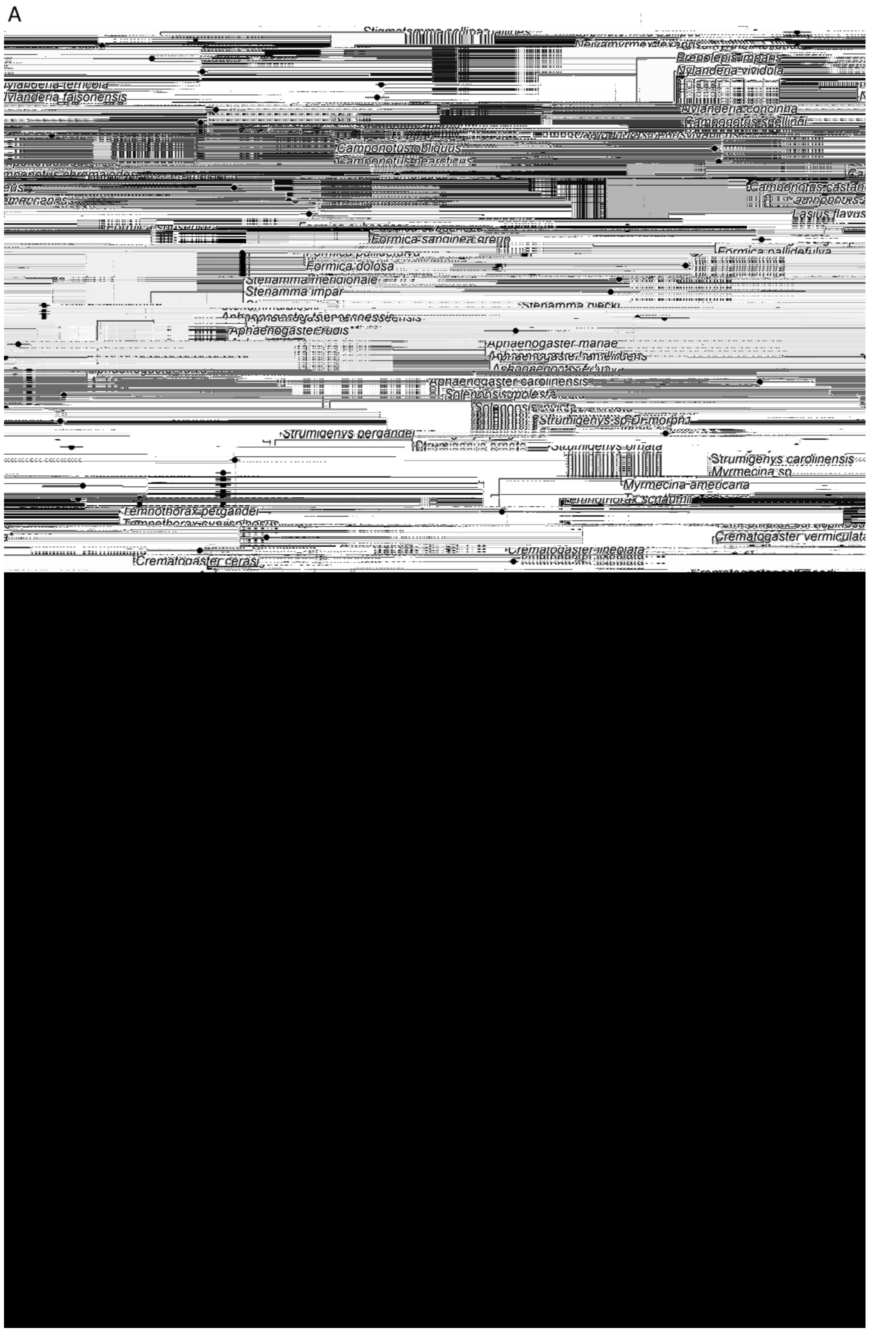

Fig. 3. Ant species responses to warming at (A) the southern site and (B) the northern site. Sites are as in Fig. 1. The slope of incidence as a function of growing degree days (GDD) is presented in context of ant phylogenetic history (Moreau and Bell 2013). The magnitudes and directions of the slopes of incidence as a function of GDD slopes indicated by distance from the zero line and positive/negative values, respectively); significance is indicated by asterisks: * , 0.05; ** , 0.01; *** , 0.001. The slopes have been scaled, but not centered, such

may be predictable based on the thermal tolerance (CT_{max}) of these species (Diamond et al. 2012 , Stuble et al. 2013). Specifically, the relationships between experimental warming and ant worker densities and foraging were significantly associated with CT_{max}, but only for ants at the southern study site. Applying the same approach to this dataset of species incidence, we found that CT_{max} was not significantly associated with the incidence–GDD slope (see Figs. 2 and 3) ($_{1,18}$, .2.8, , 0.11). Although ants with higher CT_{max} may be more active in higher temperatures (Diamond et al. 2012 , Stuble et al. 2013), other processes such as thermoregulation (Sunday et al. 2014) or changes in nest architecture (Jones and Oldroyd 2007) may allow ant species to persist in the short run

Acknowledgments

S. Pelini, L. Nichols, and K. Stuble collected data; S. Diamond, N. Gotelli, and S. Pelini performed statistical

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