Climate change and mutualism

Climate change is likely to have a profound impact on the distribution of life on this planet. As Diana Six explains, mutualistic relationships will be affected particularly severely.

Climate change will profoundly transform our biosphere. However, we have little ability to predict how the structure, function and diversity of affected ecosystems will be altered. To date, most predictive models have focused on floral or faunal communities and have been based on individual responses of target species. Few have incorporated interactions among organisms, although these can substantially alter species distributions from those predicted using single-species models, and differences in how species respond to climate change are particularly important when interactions are considered. Consequently, few studies have investigated how these differences may affect the stability of interactions or their outcomes, and only a handful have focused on symbiotic systems.

Symbioses between microorganisms and eukaryotes are widespread and many have key roles in the ecosystems in which they occur. In particular, mutualisms are important drivers of ecosystem structure and function. Through the facilitation of partners, mutualism allows organisms to excel in otherwise marginal habitats, avoid competition, exploit new niches and buffer environmental variability. For example, leaf-cutter ants are the dominant herbivores in the forests they inhabit — a role made possible by mutualisms with fungi. Coral–dinoflagellate and termite–fungus mutualisms likewise dominate their environments, where they act as ecosystem engineers. Many current and emerging pests owe their status to enhanced fitness and key innovations resulting from mutualistic associations with microbial partners.

Most mutualisms involve partnerships between ectothermic organisms. Therefore, they are particularly sensitive to changes in temperature, and most will be strongly affected by climate change. A mutualism will retain stability and function only under a particular set of environmental conditions. Because we observe mutualisms as units coexisting under the same set of environmental conditions, we often assume that partners possess identical environmental tolerances. In reality, mutualisms consist of a mix of species with different phylogenetic origins and physiologies, and considerably different responses to their environments, but that interact under a common set of conditions. The degree to which partner tolerances overlap and the breadth of conditions that this overlap spans play major parts in determining the ability of the association to remain stable under changing or variable conditions.

As the planet warms, we can expect many strong effects on mutualisms. Climate change has already altered the distributions of many species involved in mutualisms, in some cases with devastating results, as exemplified by the loss of symbionts in bleached corals in warming waters. Future changes are likely to be even more severe. Enhanced or reduced fitness of partners will occur, depending on the degree and type of change and on the individual responses of the organisms involved. Phenological mismatching of partners may lead to the decoupling of many associations and, in some cases, to extinctions. Changing temperatures may also lead to shifts in outcomes of existing symbioses (for example, mutualism shifting to parasitism or vice versa) or the formation of new partnerships. Impacts on pest or keystone mutualisms are likely to ramify throughout ecosystems. In most cases, responses will not be linear but will involve critical thresholds, past which partnerships will be permanently altered.

Climate change presents us with a grand-scale natural experiment that provides a unique opportunity to gain knowledge about many aspects of mutualism, particularly the role of the environment in controlling stability. For example, information on the responses of partners can be used to develop phenological models, which can then be used to investigate conditions that support the partnership and those that do not. Importantly, this knowledge can be extended to inform conservation efforts aimed at protecting biodiversity and ecosystem function. For instance, the same models that will be used to understand stability could be used to fine-tune predictions about the effects of warming on the geographical distributions of symbioses. Current models consider only hosts when attempting to predict geographical range expansions and contractions that are due to changing temperatures. By considering hosts and symbionts in tandem, more accurate predictions will result.

Our ability to understand, adapt to or mitigate the effects of climate change will depend on understanding its effects on biological interactions. Given the ubiquitous nature and importance of mutualism, it is imperative that we begin to devote more attention to the study of these systems in the context of climate change.

Diana L. Six is at the Department of Ecosystem Sciences, College of Forestry and Conservation, University of Montana, Missoula, Montana 59812, USA.
e-mail: diana.six@cfc.umt.edu