

## Project Summary

### Overview:

Correlational species distribution models (SDMs), which rely on the relationship between species occurrences and climate variables, have been used extensively to predict species distributions under conditions of climate change. However, SDMs have largely excluded the influence of critical biological processes, such as species interactions, local adaptation, and phenotypic plasticity, on distributions. TraitSDMs, a new trait distribution modeling approach, can provide measures of the adaptive capacity of species to climate change by incorporating trait phenotypic plasticity into projections of future spatial distributions. Traits related to the timing of biotic interactions have yet to be integrated into TraitSDMs, but would represent progress towards incorporating biotic effects into estimates of species distributions. The proposed research will use living collections of spring ephemeral species housed at arboreta and botanical gardens across the eastern United States to explore the effects of local adaptation and phenotypic plasticity on the timing of plant-animal interactions under climate change-driven range shifts. The Holden Arboretum in Kirtland, OH, will serve as the host institution (K. Stuble, sponsoring scientist), and four additional institutions (the Dawes Arboretum in Newark, OH; the Chicago Botanical Garden in Chicago, IL; the Missouri Botanical Garden in St. Louis, MO; and the Huntsville Botanical Garden in Huntsville, AL) will comprise a network of *de facto* common gardens spanning a large environmental gradient. At each institution, PI Miller will train pairs of citizen scientists to collect data on the timing of intrinsic (leaf-out, flowering, fruiting) and extrinsic (pollination, seed dispersal, herbivory) phenological events for living accessions of *Trillium recurvatum*, *Sanguinaria canadensis*, and *Stylophorum diphyllum*, model spring ephemeral species. These data will be integrated into TraitSDMs for each species, which will use source and site climate data to project spatial distributions of traits. Correlational SDMs will also be built for each species under current and future climate scenarios, and the spatial projections from TraitSDMs and correlational SDMs will be integrated to obtain novel scenarios of distribution change and to determine whether phenological traits can provide species the capacity to adapt to climate change.

### Intellectual Merit:

This research will establish whether phenotypic plasticity of plant phenological traits can facilitate rapid adaptation to climate change. Understanding the effects of phenotypic plasticity on phenological events, particularly those related to critical biotic interactions, will significantly improve predictions of species distributions under climate change. This project will employ a combination of observational, experimental, and computational approaches to elucidate the mechanistic relationships between plant phenomes, trait plasticity, species interactions, and climate across a broad environmental gradient spanning hierarchical levels of analysis, from individual organisms to regional communities. The research will translate observational datasets collected across a network of living plant collections into a novel modeling framework combining TraitSDMs and correlational SDMs. This powerful integration of models will establish a novel computational method for incorporating phenotypic plasticity related to phenology into predictions of species distributions, applicable across diverse biological systems. Finally, the use of citizen science initiatives to generate data across a network of American Public Garden Association institutions will bridge the gap between scientific research and broader societal endeavors.

### Broader Impacts:

This research will result in peer-reviewed publications and conference presentations that will further establish PI Miller as an expert in the fields of climate change, species interactions, and species distributions, and will allow her to experience non-academic research. Forging relationships with scientists at the host and partner institutions will provide Miller with an invaluable working network that she will be able to build on in her future career working at the interface of academic and non-academic research. In addition, this project will engage citizen scientists at each institution who will be provided hands-on training by PI Miller. To further develop pedagogical and mentoring skills, Miller will work with the Holden Arboretum's education department to plan public programs and educational content based on the proposed research. Miller will also develop a spring wildflower hike targeted at underserved youth with the Cleveland Footpath Foundation. Finally, focusing on underrepresented groups in STEM, Miller will engage and mentor local students in independent research related to the proposed research.