Leveraging museum collections and digitized data to explore climate-influenced plant movements in the Americas

Overview

Studying how biodiversity has responded to past instances of climate change provides a critical framework for predicting how species and ecosystems will respond to ongoing climatic changes and habitat destruction during the Anthropocene. Our ability to study plant evolutionary responses to climate change is aided greatly by digitized biodiversity data, but to date, few major herbaria have been fully digitized. The US National Herbarium (NMNH), as one of the first fully digitized major herbaria, is therefore in a unique position to tackle major research questions about how plants respond to global change. For this project, the fellow will leverage this exceptional resource to study plant evolution and biogeography in the Americas, with a focus on how climate change over the past 14 million years has shaped plant movements, speciation, and extinction, and how these processes have contributed to the assembly of modern temperate forest communities.

Importance

The transition between a 'Greenhouse' and 'Icehouse' climate on Earth profoundly impacted ecosystems across the globe. The intensification of Icehouse conditions over the past 14 million years, involving widespread cooling and aridification as well as glacial/interglacial cycles, led to major changes in plant distributions, widespread extinction, and instances of adaptive radiation and diversification. These processes fundamentally shaped the formation of modern ecosystems. Studying the dynamics of plant migration, speciation, and community assembly during this tumultuous period of geologic history represents one of our best opportunities for understanding not only the origins of modern-day plant communities, but also for predicting how these communities, and the species that comprise them, will respond to the ongoing pressures of the Anthropocene.

A particularly valuable lens for understanding the dynamics of plant migration and diversification in response to climate change is through the study of biogeographic disjunction patterns (Wen 1999), where multiple taxonomic groups are shared between isolated geographic areas. Study of biogeographic movements can provide unrivaled insight not only into the historical assembly of modern biotas, but also into fundamental biological processes of evolutionary responses to climate change. Surprisingly, one of the best systems for studying the dynamics of temperate plant diversity in the Northern Hemisphere has been largely unstudied: the biogeographic pattern involving lineages that are disjunct between eastern North America and cloud forests of Mesoamerica (MAM), with well-known examples including sugar maple, grapes, hickories, dogwood, sweetgum, and redbud. Recent work has revealed >100 examples of this disjunction pattern in seed plants alone (Stull 2023). Preliminary work suggests that many cloud forest populations likely represent undescribed species. Available evidence also suggests that different climatic events (Mid-Miocene climatic Optimum, late Miocene aridification, and Pleistocene glaciation) have contribution to the formation of this disjunction pattern, making it a particularly attractive system for studying plant migrations across the Americas at different points of the Cenozoic. Overall, this represents an incredibly rich—and grossly understudied—system for studying the evolutionary and ecological responses of American temperate and cloud forests to climate change, guiding conservation efforts, and for bolstering relationships between US and Mexican botanists to tackle urgent problems in biodiversity science.

Potential Research Themes

This project will pursue the following research objectives:

(1) Examine plant responses (including migration, diversification, and extinction) to major episodes of climate change. These include the mid Miocene climatic optimum, late Miocene cooling and aridification, and Pleistocene glaciation. This will offer predictive power for how plant communities will respond to ongoing and future climate change through the Anthropocene. **(2)** Determine how different plant attributes (growth form, pollination mode, dispersal mode) influence a given species' ability to move or evolve in response to climate change. This will help us determine which species might be most threatened by pressures including climatic warming and human disturbance. **(3)** Use collections data to accelerate biodiversity discovery focusing on poorly collected hotspot regions, including cloud forest communities of Mesoamerica and Southeastern North America. **(4)** Use collections data to identify critical collection gaps for temperate and cloud forests across the Americas to guide future field expeditions to capture biodiversity for the next century. Filling such gaps will be critical for biodiversity discovery and documenting distribution changes during the Anthropocene. **(5)** Establish a model to train early-career scientists and high school interns on biodiversity informatics and genomics to address fundamental questions on climate change utilizing natural history collections. **(6)** Engage and educate the public on the critical role of natural history museums in the new age of biodiversity discovery and climate change.

PROGRAMS AND ASSETS

This project will leverage the world-class, completely digitized collections of the US National Herbarium (NMNH) along with other recently digitized resources (Soltis 2017) and the vast natural history plant collections to study the impact of recent climate change on the migration/movement dynamics of plant species of temperate and cloud forests in the Americas. Through this work we will stimulate collaborative research and build partnerships to address grand questions related to the current biodiversity crisis. This includes tackling the urgent need to accelerate biodiversity discovery using museum collections, digitized data, and emerging biodiversity informatic and genomic tools. The project will involve scientific collaborations among scientists from different Smithsonian units (NMNH, ForestGEO, Data Science Lab of OCIO) as well as with botanists from Mesoamerica, particularly Mexico.

ADVISORS

Smithsonian botanist Jun Wen will serve as the primary advisor, and the project will be developed closely with Smithsonian Botany curators and collections, NMNH informatics team, and the following Smithsonian staff scientists (Stuart Davies, Scott Wing, and Rebecca Dikow).

ADVISORS

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