Researchers reveal the biogeographical patterns of fern diversity

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In a new study in the *Journal of Biogeography* an international team of researchers led by Harvard University assembled one of the largest global assessment of fern diversity. The study integrated digitized herbarium data, genetic data, and climatic data and discovered 58% of fern species occur in eight principally montane hotspots that comprise only 7% of Earth's land area. And within these hotspots, patterns of heightened diversity were amplified at higher elevations above 1000 meters. Credit: Copyright 2021 Jacob Suissa.

Earth is home to millions of known species of plants and animals, but by no means are they distributed evenly. For instance, rainforests cover less than 2 percent of Earth's total surface, yet they are home to 50 percent of Earth's species. Oceans account for 71 percent of Earth's total surface but contain only 15 percent of Earth's species. What drives this uneven distribution of species on Earth is a major question for scientists.

In a paper published February 16 in the *Journal of Biogeography* an international team of researchers led by Jacob S. Suissa, Ph.D. Candidate in the Department of Organismic and Evolutionary Biology, Harvard University, and co-authors Michael A. Sundue, University of Vermont, Burlington, and Weston L. Testo, University of Gothenburg, Sweden, assembled the first global assessment of fern diversity. The study integrated digitized herbarium data, genetic data, and climatic data to determine where most fern species occur and why.

The researchers relied on recently digitized natural history collections to map the diversity of life on earth and build a database of over one million fern specimens with longitude and latitude coordinates occurring all over the world. After an extensive cleaning of the database to remove records with poor coordinates roughly 800,000 occurrence records remained. They then divided the earth into one-degree latitude by longitude grid cells and determined the number of species occurring within each cell. The researchers discovered that the majority of fern species occur in eight principally montane hotspots: Greater Antilles, Mesoamerica, tropical Andes, Guianas, Southeastern Brazil, Madagascar, Malesia and East Asia.

"Natural history collections are the primary data for all biodiversity studies, and they are the backbone to this study," said Sundue. "Scientists have been making collections and curating them for hundreds of years. But only recently, the digitization of these records has allowed us to harness their collective power."

Testo agreed, "There has been a large effort over the last decade to digitize the impressive collection of specimens contributed by thousands of collectors and experts in the field and deposited in museums or natural history collections. For this study we used over 800,000 digitized occurrence records for nearly 8,000 fern species."

The research was conducted in multiple phases and each phase built upon the previous. "The first thing we wanted to know is where are the centers of ferns' biodiversity, and second, why?" Suissa said. "We wanted to understand the biogeographical patterns of fern diversity. Understanding these patterns in a major plant lineage like ferns, allows us to take a step towards understanding why there is an uneven distribution of species around the world."

One major finding is that 58 percent of fern species occur in eight principally montane biodiversity hotspots that comprise only 7 percent of Earth's land area. They also found that within these hotspots, patterns of heightened diversity were amplified at elevations greater than 1000 meters above sea level.

"On a global scale we find a peak in species richness per area around 2000 to 3000 meters in elevation, roughly midway up some of these tropical mountains," explained Suissa. "And we think this is primarily due to a very unique ecosystem that occurs in this elevation band, which in the tropics is the cloud forest."

While ferns grow in a variety of ecosystems, including moist shaded forest understories and rocky desert outcrops, many species are actually epiphytic, meaning they grow on the branches of trees. Suissa and colleagues believe these epiphytes explain the mid to upper elevation peak in species richness of ferns in the tropics.

Once the researchers determined the biogeographical patterns of fern

diversity, they investigated why these particular patterns exist. Examining ecological data, including climate and soil data, they showed that within each hotspot there was a strong correlation between increased climatic space and increased species richness and diversification; suggesting that ferns occurring in tropical mountains are forming new species more rapidly than those elsewhere.

"People tend to think of places such as the Amazon rainforest as biodiversity hotspots," said Suissa. "But for ferns, it is tropical and subtropical mountains that harbor a disproportionate number of rapidly diversifying species relative to the land area they occupy. Ferns may be speciating within these tropical mountain systems because of the variation in habitats that occur across elevational gradients. For instance, at the base of a tropical mountain it is hot all year round, and at the summit it is perennially cold. Essentially, these dynamics create many different ecosystems within a small geographic space."

Unlike mountains in temperate regions, the tropics have very low temperature seasonality. This means that each ecosystem across an elevational transect in a tropical mountain remains roughly the same temperature year-round. Effectively, it is harder for plant and animal species to move between elevational zones if they are adapted to one spot on the mountain. Researchers think that these dynamics between the difference in climates at different elevations and the climatic stability within each elevational site allow for plants and animals to diversify more rapidly in tropical mountains.

Going forward the researchers hope to conduct more small-scale population-based studies in young tropical mountains to physically test these hypotheses, and to hopefully also add more specimens and continue to expand digitization of museum collections for study.

More information: Jacob S. Suissa, Michael A. Sundue, Weston L.

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