New analysis suggests that preserving rare species is vital to tropical forests

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The world's tropical forests are in "a critical state" in which the extinction of rare tree species could be a tipping point, say scientists who have developed an analytical method to map their biodiversity.

"We are in the midst of an extinction crisis," said Jayanth R. Banavar, provost and senior vice president at the University of Oregon and previously at the University of Maryland in College Park. "We are losing species perhaps more rapidly than ever before. It is the biodiversity of the species that keeps our planet the way it is. These species have evolved over many, many millennia. A species once lost is gone forever."

In a paper published Oct. 18 in the journal *Science Advances*, Banavar, a physicist, and co-authors from three other universities unveiled their findings, which are based on a mathematical framework relying on a mechanistic birth-death-immigration model of an ecosystem.

The species abundance distribution studied by the scientists, known in the math world as negative binomials, is a generalization of the log-series proposed in 1943 by R.A. Fisher of the University of Cambridge to understand the overall abundance of British moth species based on numbers found in a small sample.

Currently used approaches, Banavar said, have limitations that often produce inaccurate extrapolations when scaling up from a given sample size to the scale of the entire forest.

About two-fifths of the world's trees are in tropical or subtropical forests. Yet far less than 1 percent of tree species are known. The new method identifies minimum sampling sizes needed for accurately projecting numbers of abundant and rare trees across forest regions. Species with few trees are at risk for extinction.

"We find that the tropical forest in Panama already has sufficient monitoring, while other forests, such as that of the Amazon, still require extensive additional sampling," said study co-author Amos Maritan of the University of Padova in Italy.

The researchers suggest that the numerous extremely rare species may be vitally important to maintaining biodiversity and survival as forests undergo worldwide climate change and human activities.

"Boosting biodiversity is not only of utmost importance for our planet's survival, it is also a mathematical problem of great interest that had already been engaged by many ecologists," Banavar said. "We have developed a method that gives accurate estimates of the number of species and abundances present in the entire ecosystem."

The new method, he said, is based on local scale information and the neutral ecological theory of Stephen Hubbell of the University of California, Los Angeles, and Smithsonian Tropical Research Institute in Panama. It emerged in a 2007 Nature paper that looked at distinct behaviors of coral reefs and tropical forests. Banavar and Maritan were co-authors, along with Igor Volkov of the University of Maryland in College Park, also a co-author of the new research.

For the new research, the methodology was further adapted and tested on forest species populations both in computer simulations and on available data from 15 different tropical forests.

"Our approach shows that, on a global scale, relatively few species account for more than 50 percent of individual trees, while a high percentage of species have less than 1,000 trees," Maritan said. "In our interpretation, this indicates that the analyzed ecosystems behave as though they are poised in the vicinity of a critical point—a well-studied phenomenon in phase transitions in physical systems. Such systems tend to be exquisitely sensitive to tiny perturbations."

The traditional method begins with the hypothesis that a species-abundance distribution is a Fisher log-series, but that assumption skews actual species numbers in scaling efforts, Banavar said.

Dramatic reductions of estimates for "hyper-rare" tree species using the new methodology were seen in four of the forests included in the study: Caxiuna and Manaus, both in the Amazon, Nouabale in the Republic of Congo, and Volcan Barva in Costa Rica.

"As we sample more and more, we tend to see the same species again and again, so the shape of the curve shifts to where we no longer have the largest number of species with very tiny numbers of individuals but rather we have larger numbers of species with intermediate numbers of individuals. If you go to a real forest, this is what you will find."

The new approach, Banavar said, allowed the team to address a simple question: How many species of trees are, in fact, present in the Amazon or in other forests? And how many of them are rare and at risk for extinction?

Small fluctuations, he said, could lead to wholesale changes in forest diversity and health. Rare species, he said, provide a reservoir for recovery and forest resilience.

"This method allows us to understand both how fragile the biodiversity is and how many species we should be focusing on with conservation efforts," Banavar said. "As caretakers of this planet, we want to nurture the species that we have, and we want to preserve life for the next generation."

The new method, Maritan added, is simple and could be applied in other areas such as understanding the biodiversity of the microbiome.

"We present a proof that any shape of a species-abundance distribution, even with weird peaks, can be expressed exactly as a linear combination of these negative binomials. And the up-scaling procedure can be exactly derived under certain simplifying assumptions," he said.

More information: "Upscaling species richness and abundances in tropical forests," *Science Advances* (2017). DOI: 10.1126/sciadv.1701438 , advances.sciencemag.org/content/3/10/e1701438

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