Spatial aspects of biodiversity and the homogenization threat to forest ecosystems

June 1 2022, by Talia Ogliore

A study from the Missouri Ozarks highlights the importance of spatial aspects of biodiversity for healthy functioning of naturally occurring forests. Jacqueline Reu, first author of the study in the journal Ecology, graduated from Washington University in 2019 with a double major in environmental biology and in physics in Arts & Sciences. Credit: Jonathan Myers

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Biologists from Washington University in St. Louis determined that tree beta diversity—a measure of site-to-site variation in the composition of species present within a given area—matters more for ecosystem functioning than other components of biodiversity at larger scales. The research also shows that the relationship between beta diversity and tree biomass strengthens with increasing spatial scale (the size of an area), a finding that has implications for conservation planning. The study was published in the journal *Ecology*.

The study was led by Jacqueline Reu, who graduated from Washington University in 2019 with a double major in environmental biology and in physics in Arts & Sciences, as part of her honors thesis in biology. Reu was mentored by Christopher P. Catano, a Ph.D. graduate of Washington University who is now a postdoctoral research associate at Michigan State University, and Jonathan A. Myers, associate professor of biology in Arts & Sciences at Washington University.

The data for Reu's thesis was collected as part of a large-scale forest ecology project led by Myers' research team at Tyson Research Center, Washington University's environmental field station. More than 60 undergraduate students, high school students and research technicians have surveyed more than 30,000 trees for the project.

"A lot of studies have focused only on small scales when they look at biodiversity and ecosystem functioning," said Reu, first author of the study. "Our study is one of the first that looks at multiple different measures of biodiversity, as well as direct and indirect effects of the environment, on ecosystem functioning as you increase scale in a natural system."

"Our results back the theory that beta diversity, or the variation in species composition across space, is the best biodiversity measure at larger scales," she said. "It's stronger than the other diversity measures

that we considered, like local and regional diversity. And its importance increases as you increase spatial scale."

Studying landscapes in the Ozarks

For this study, researchers identified 14 landscapes of oak-hickory forest, each of which contained at least three major habitat types that are often found in Ozarks forests, including west- or south-facing slopes that tend to be sunnier, drier and nutrient poor; valleys and bottom lands, which are often shady, nutrient-rich and have small streams running through them; and east- and north-facing slopes, which tend to be the most productive in terms of tree cover.

Each landscape included an environmental gradient of nutrient and moisture availability, light availability and a variety of topographic conditions.

A black oak tree (Quercus velutina) encircled by a liana vine (Vitus sp.) at

Washington University's environmental field station, Tyson Research Center, located near Eureka, Mo. Credit: Jonathan Myers

The scientists quantified the direct effects of three different diversity components—beta diversity, local diversity (the average number of species present in a small area) and regional diversity (the total number of species in the larger landscape)—and then calculated the strength of the relationship between each diversity component and the aboveground tree biomass, a property of forests related to ecosystem functioning.

Finally, they considered the strength of these relationships across 11 spatial scales within each of the landscapes, ranging from 20×20m to 120×120m. (For comparison, that's a difference in size ranging from about the size of an end zone in American football to about 2.6 football fields.)

"It's been a thorny thing in ecology—and most sciences, really—to try to identify the scale that we should use to study a system," said Catano, who co-led the new study. "It leads to a lot of controversy and a lot of confusion."

Other studies have drawn similar connections between beta diversity and ecosystem functioning, but those previous studies tended to rely on comparisons drawn on small plots of land.

Understanding how and why the relationship between beta diversity and ecosystem functioning scales up is a high-stakes analysis, in part because scientists are struggling to map out the myriad consequences of biodiversity loss in recent decades.

"It's not just the gain or the loss and the number of species that matters,

it's also changes in the distribution of these species and where you might find them in an ecosystem," Catano said. "This study and a few others recently have been pretty consistent, in the sense that they're showing it's (species) turnover, or variation across space, that seems to be really critical.

"(Beta diversity) is driving a variety of different functions, as well as the stability of these functions over time, as you scale up from small, local plot-based ecosystems to large, heterogeneous landscapes," he said.

"This project highlights the utility of large-scale, long-term field research projects," Myers said. "The study was largely fortuitous, because we had set up the 14 large forest plots across the Tyson landscape for a different project. But the way that we set them up was perfect for addressing questions about how environmental variation and species composition across space contribute to ecosystem functioning.

"One implication is that if you homogenize the environmental conditions, that might also negatively impact ecosystem functioning," Myers said. "Habitat loss or homogenizing the amount of nutrients and other limiting resources for organisms in an ecosystem could have cascading effects on ecosystem functioning and services. These are indirect effects that are challenging to predict if you don't consider both environment and diversity together."

Washington University's Tyson Research Center, located 20 miles southwest of the Danforth Campus, provides rich, collaborative field opportunities for both scientists and students. Credit: Thomas Malkowicz/Washington University

Monitoring ecosystem functioning

Since graduating from Washington University, the study's first author, Reu, has worked as an intern at the Smithsonian Marine Station at Fort Pierce, Fla., and at the Smithsonian Environmental Research Center's Marine Invasions Lab in Tiburon, Calif. But she continues to be motivated by her work at Tyson Research Center.

"Forests are my favorite ecosystem to be in," Reu said. "Without plants, nothing else in the food chain would work at all: it wouldn't exist. And

that's why I find studying them especially fascinating."

During the hot, humid days of her undergraduate summers, Reu tramped through the forest with a small squad of other Tyson research fellows—identifying trees, measuring their diameters and tagging and mapping them as part of a long-term forest monitoring program. Reu identified seeds collected from seed traps and cleaned, weighed and cataloged seedlings. At night, she taught herself a statistical programming language to help sort through the data she was recording.

"I've always liked the math side of things," Reu said. "For this project, I mostly taught myself to program in R, using YouTube videos.

"It wasn't the first computer language I've learned, but I think it's the most thorough one I've learned so far," she said. "Then I made some graphics using GIS as well."

This coming summer, Reu will be doing a project with rare butterflies in New Hampshire while she prepares to apply for graduate school.

"I've always had a passion for ecology," Reu said. "So when I was just looking at different options, Jonathan's lab really stood out to me. He's so inventive and they do really thorough work.

"And I love trees, so that definitely helped," she said. "The work at Tyson was very interesting, partly because it's part of the Smithsonian Forest Global Earth Observatory (ForestGEO) network. That just opens a lot of doors."

More information: Jacqueline C. Reu et al, Beta diversity as a driver of forest biomass across spatial scales, *Ecology* (2022). DOI: 10.1002/ecy.3774