

horizons

DISCOVERY AND INNOVATION FROM NORTHERN ARIZONA UNIVERSITY

Roots of understanding

Unearthing the hidden power of the tree gene

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The Cottonwood Connection

Tree genes tied to ecosystem evolution

Standing in a room full of people, it's easy to see individual differences in hair color, skin tone and facial features. Standing in a forest, one tree looks pretty much like another. However, just as with humans, genetics make each tree uniquely different.

A group of scientists suggests that genes, which control individual characteristics of a particular tree, may also influence the characteristics of the entire ecosystem in which that tree lives—from the microbes in the soil to the animals that make the forest home. These tree traits, they say, drive the evolution of the ecosystem.

The effort to prove such a theory would seem daunting at best, given the thousands of plant and animal species that constitute even simple communities. But lead investigator Tom Whitham of Northern Arizona University's Biological Sciences Department and his team of researchers have developed a model system.

"We're pushing a whole new field of research," Whitham acknowledges of their work to establish a framework for ecosystem genetics.

"What we've done is zero in on a foundation species, because not all species are as equally important ecologically," Whitham said. The foundation, or key, species in this case is the cottonwood tree, which is the first tree to have all its genes sequenced, or mapped.

Domino effect

Among the genes under study are those that control the level of tannins in cottonwoods, which are dominant trees in riparian habitats in the West. Different cottonwood trees have different levels of tannins. (Tannins are what give wine an astringent taste and are also used in leather tanning.)

These tannin levels drive the structure of a riparian forest, according to Whitham. As he explains, tannins affect the decomposition rate of cottonwood leaves, which in turn affects the fertility of soils, which affects the microbes in the soil, which affect the insects that live in the soil or eat the leaves, which affect the birds that feed on the insects, and so on.

"What we looked at were the indirect genetic effects of one species on other species," said Stephen Shuster, co-researcher and NAU professor of biological sciences. More specifically, they discovered how the genotype of one organism influences the phenotype of other species.

By Lisa Nelson



Illustration by Laura Williams



“It’s not enough to save rare and endangered species. We

need to preserve genetic diversity in the foundation species.”

A couple of definitions are helpful here. Genotype is the internal genetic makeup of an organism—its DNA. Phenotype refers to the exterior observable traits of organisms.

What the research group says is that the genetically controlled tannins of the cottonwood (genotype) influence the biologic structure (phenotype) of the ecosystem.

“The assumption was you couldn’t track this [genetic influence] because there are so many species involved,” Shuster says. “What struck me was all the information the research group had on the biology associated with cottonwood trees.”

The abundance of data helped Shuster in his quantitative genetic analysis.

Not only did the team pinpoint this genetic influence, it also demonstrated it is inherited. That is, the offspring of cottonwood trees will support the same communities of organisms and ecosystem processes that their parents supported.

“The traditionally held belief is that communities are assemblages of organisms, not evolved units. This research suggests that communities are not necessarily static assemblages, but are highly dynamic systems,” says Shuster.

Their work has been published in *Nature Reviews Genetics* and the journal *Evolution*.

Increased diversity

It’s a premise with far-reaching implications. Consider, for example, conservation efforts to preserve biodiversity in the face of habitat destruction, climate change, and other impacts on the environment. Planting trees that are genetically diverse will result in increased diversity of other species in the dependent community. The greater the tree

diversity, the greater the chance of associated species surviving environmental degradation.

“It’s not enough to save rare and endangered species. We need to save genetic diversity in the foundation species,” says Jennifer Schweitzer, co-author of the *Nature Reviews Genetics* paper and postdoctoral researcher at NAU.

“Having high genetic diversity in these foundation species is insurance against changes in the future.”

The research also has ramifications when it comes to genetically modified organisms and their effects on the landscapes in which they are introduced. For example, grasses that are genetically altered to prevent weed growth could pass that resistance along to exotic plants, which then might take over a community and change the evolution of that ecosystem.

More than fifty researchers from the United States, Canada, and Australia are studying this genetic driver of community structure and ecosystem evolution. The work is funded by a \$5 million Frontiers in Integrative Biological Research grant from the National Science Foundation. The project includes scientists from a multitude of disciplines because, as Whitham says, “No one person has all the skills to do this.”

“This is an exciting project with global impact, drawing on the expertise of geneticists, ecologists, molecular biologists, biogeographers, and others,” says Chris Greer, program director at the National Science Foundation. “The results are expected to not only shed light on how complex biological communities function but to inform efforts to address the impact of human activities, such as landscape fragmentation, on stressed ecosystems across the planet.” NAU

lead investigator:



THOMAS WHITHAM

Regents’ Professor, Department of Biological Sciences

Education: B.S. in plant pathology and horticulture from Iowa State University; M.S. in zoology from Ohio State University; Ph.D. in biology from the University of Utah

Expertise: population and community ecology, ecological genetics and plant-herbivore interactions

Study gardens reap restoration benefits

To study the genetic framework of ecosystems in the wild, Tom Whitham and his team have planted several experimental “common gardens” of cottonwoods in Arizona and Utah.

The trees are propagated at NAU’s research greenhouse. Through DNA fingerprinting in NAU’s Environmental Genetics and Genomics facility, the scientists know the precise genetic makeup of each tree.

In one experiment, Whitham’s group worked with the Bureau of Reclamation to plant about 10,000 trees at the Cibola National Wildlife Refuge along the lower Colorado River, about 20 miles south of Blythe, California. The purpose was to examine how genetic diversity at the stand level can have a positive effect on the biodiversity and provide habitat for rare species.

“The Bureau of Reclamation gets restoration out of this project, and we get this incredible experiment,” says Whitham.

All of the experiments, so far, have exceeded the researchers’ expectations. “Initially we thought that the [genetic influences] would be more localized and that environmental effects would be most important as we moved beyond the local common garden setting to all of the western U.S.” In the end, however, Whitham says, “Plant genes are far more important than we ever expected them to be.”

Now the researchers want to know if their findings hold true in different environments around the world. “To understand how important something is, you have to test in multiple locations,” Whitham says.

A parallel study in Australia that examines the eucalyptus tree as the foundation species is yielding the same results as the studies on cottonwoods. And Whitham has just returned from South Africa and Borneo in Southeast Asia, where he is planting the seeds for further study.



PHOTOGRAPHY BY (LEFT) MICHAEL MERTZ