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ECOLOGY

When Juniper and Woody Plants Invade, Water May Retreat

Dense plants are taking over grasslands in many areas; researchers in the U.S. Southwest are studying how they tap into water supplies—and how to keep them in check

AUSTIN—The day is hot and humid, as Robert Jackson descends into the mouth of Powell Cave and down a ladder that drops into the limestone bedrock of the Edwards Plateau about 240 kilometers west of Austin. He follows an ancient streambed through several large caverns and a few tight crawl spaces, until he arrives at a point about 18 meters below the surface, where a crystal-clear stream bubbles out of the rock.

Several thick tree roots burst out from the limestone, reach down, and suck moisture from the water. Some of them have been wired with electronic probes. Applying pulses of heat, Jackson and his lab can gauge water flow by how fast that heat dissipates. Jackson, a biologist at Duke University in Durham, North Carolina, is investigating how roots transfer water from this depth up to the surface. "A single taproot can provide a third or more of the tree's water during a drought," says Jackson.

His study aims to determine what enables juniper to survive in these arid environments and how much ground water they are using. Funded by the U.S. National Science Foundation, the U.S. Department of Agriculture, and the Andrew W. Mellon Foundation, this research indicates that wildlife and water management would benefit from fewer of these trees.

Woody shrubs and trees like juniper have in recent decades replaced arid and semiarid grasslands and savannas throughout much of the western United States, from the Great Plains to the Gulf Coast. "Encroachment of woody plants limits the amount of forage available to livestock, alters the natural landscape for native wildlife, impedes the flow of water available at the surface, and creates conditions for more catastrophic fires," Jackson says.

With global warming predictions calling for increased droughts, expansion could continue. And it's not just a U.S. problem: The shrubs and trees are proliferating in grasslands and savannas in South America, Africa, and Australia.

Depleted streams

The effect of expanding woodlands on water flow can be dramatic. Kathleen Farley of San Diego State University in California and Jackson reviewed data sets from efforts to establish new forests in Africa, New Zealand, Australia, and Europe and found that increased tree and shrub growth typically resulted in the loss of one-third to three-quarters of stream flow. "In areas where natural runoff is less than 10% of mean annual precipitation, afforestation can result in complete loss of runoff," says Farley. As a consequence, some say, afforestation efforts that have been proposed as carbon offsets need close scrutiny.

The same types of growth appear to be draining water from the Swiss-cheese structure of the limestone bedrock, known as karst, on the Edwards Plateau. Such systems cover one-fifth of Texas and 7% to 10% of the globe's land surface. This area in Texas gets about 63.5 centimeters of rain a year, yet there are few aboveground streams. Jackson's research shows that the drinking habits of these trees may be partly responsible.

One hundred and fifty years ago, this area was comprised of grasslands and savanna where oak trees dotted the landscape. They were more frequently swept by wildfires, one of several factors that kept woody plants at bay. "There is likely no single driver" of the change to denser growth, says Steve Archer, a professor at the School of Natural Resources at the University of Arizona, Tucson. Fire suppression, overgrazing, droughts, and climate change have all played a part in helping woody plants succeed, he says.

Juniper is the dominant woody invader throughout much of the Great Plains and the West, but mesquite plays a role in the southern Great Plains and the Southwest, creosote in the Southwest, and Chinese tallow in the Gulf Coast Prairies. Juniper and mesquite have invaded the plateau, forming dense monocultures in which birds and wildlife don't do well. Black-capped vireos and golden-cheeked warblers, two Texas birds that are both endangered, are among those that require a mixed-forest habitat to thrive.

Large mammals are affected as well. The bighorn sheep of New Mexico, already endangered, are increasingly threatened by attack from mountain lions, which are moving into wooded mountaintops that were bald in the past. According to Eric Rominger, a bighorn sheep biologist at the New Mexico

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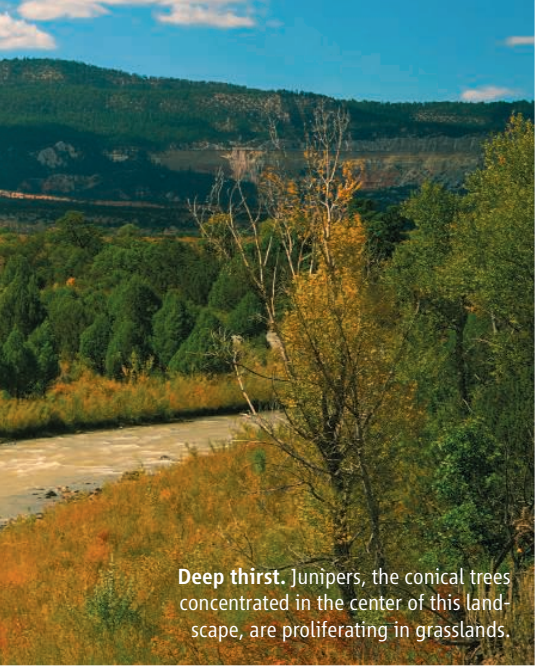

Deep thirst. Junipers, the conical trees concentrated in the center of this landscape, are proliferating in grasslands.

Department of Game and Fish in Santa Fe, "Mountain lions are ambush predators, and they need cover to launch their attacks." The emboldened predators are also taking a toll on ranchers' livestock, mainly young cattle.

Thickets

One goal of Jackson's study is to learn how these trees survive drought. Finding water is only half the battle. All woody plants have to lift that water aboveground, which they do by creating an evaporative flow. The leaves are speckled with pores that open to absorb carbon dioxide (CO_2). The leaves of a juniper are needlelike, or awl-shaped. When the pores open, they release moisture, setting up a powerful vacuum through short, interconnected passages called tracheids that draw moisture from the tree's root system in the same way one might pull soda through a straw. "When a tree doesn't have enough water to conduct this process, it doesn't die of thirst but of starvation"—because the intake of CO_2 drops, and "it can't fix carbon to make food," says Jackson.

Tim Bleby, a research associate at the University of Western Australia in Perth, who worked with Jackson, studied root water uptake in juniper and found that water is delivered from one part of the tree to another to equalize water distribution. This gives such plants, which have multilevel root systems, a distinct advantage over shallow-rooted grasses. "When the surface is dry, they use deep roots; when it rains, they switch over to shallow roots."

The water-uptake mechanisms of juniper aren't fundamentally different from those of other woody plants, just more efficient. Cynthia Wilson, a former Ph.D. student in Jackson's lab, sampled junipers all over the West and then studied them for anatomy, wood density, hydraulic conductivity, and resistance to cavitation, or the formation of bubbles that interrupt the flow of water through the tracheids. Cavitation resistance is a marker for drought resistance. Wilson took branches from different junipers and spun them in a centrifuge, mimicking conditions under which the branches would cavitate and no longer transport water. According to Wilson, "Juniper are among the most cavitation-resistant tree species ever studied."

These attributes, coupled with fire suppression and overgrazing, have given woody plants like juniper an advantage in the West. Archer refers to the result as "thicketization." Says Archer: "When we introduced grazing in the West in the late 1800s, fine-grass fuels were removed, and that greatly reduced fire frequency. Woody plants then had wider windows of opportunity to establish and become large enough to resist the effects of future fires."

Pushing back

Ranchers and land managers have been fighting woody encroachment for years using everything from chemicals to goats. The straightforward approach—deploying chain saws and bulldozers—can be effective.

For example, New Mexico has hired crews to cut piñon pine and juniper on sheep habitat, part of a management process including relocation and predator control that may soon see this animal downlisted. But Archer warns against trying to stop the woody invasion with a "wall-to-wall clearing of brush." It's critical, he says, to take account of plants' "historical distribution and abundance."

Some groups have developed clever ways to use brush control to restore historical grasslands. Jackson cites the example of J. David Bamberger, a co-founder of the Church's Fried Chicken franchise. Bamberger has been clearing juniper thickets on his land since 1969 and replanting them with grass. According to Colleen Gardner, executive director of the Bamberger Ranch Preserve in Johnson City, Texas, the ranch has established a native mix of grasses that includes 80 species and has restored 27 ponds and lakes.

Biologist Marsha May of Texas Parks and Wildlife conducts tri-annual Audubon bird counts on the ranch and notes that the counts have grown from 48 to 205 species. She and other state biologists have located breeding pairs of black-capped vireos and golden-cheeked warblers on the property.

Texas A&M University scientists conducted research on shrub control and water yield that addresses different vegetation types and geographic zones on the Edwards Plateau. The Edwards Aquifer Authority, in conjunction with the Natural Resources Conservation Service, is using the study as a basis to provide cash assistance to ranchers and land managers to help clear mesquite and juniper thickets from their lands. Ranchers can get as much as 70% of their expenses back. Texas Parks and Wildlife has a program to assist landowners with what they call "brush sculpting," a careful method to return a property to historical purposes.

If successful, the effort should help increase water flow as far away as San Antonio and Austin. Says Jackson: "It's not the typical case where you're faced with environmental and economic tradeoffs. Brush clearing here has advantages for water availability, forage production, and native wildlife. We are reaping multiple benefits."

–MICHAEL TENNESEN

Tapping in. Biologist Robert Jackson wires up tree roots in Texas's Edwards Plateau to monitor their water uptake.

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