Intensive water management in California promotes 'live fast, die young' cycle in floodplain forests

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Riparian community woodlands along the lower Tuolumne River near Merced, California. The dry grassland in the background indicates the semi-arid conditions and drought environment. Credit: JOHN STELLA, ESF

Woodlands along streams and rivers are an important part of California's diverse ecology. They are biodiversity hotspots, providing various ecosystem services including carbon sequestration and critical habitat for threatened and endangered species. But our land and water use have significantly impacted these ecosystems, sometimes in unexpected ways.

A team of researchers, including two at UC Santa Barbara, discovered that some riparian woodlands are benefitting from water that humans divert for our own needs. Although it seems like a boon to these ecosystems, the artificial supply of water begets an unintended dependence on this bounty, threatening the long-term survival of natural forest communities. The paper, published in the *Proceedings of the National Academy of Sciences,* spotlights the need for changes in the way water is managed across the state.

"We need to be more intentional in incorporating ecosystem water needs when we manage water—both for aquatic organisms and species on land," said lead author Melissa Rohde, a groundwater scientist at The Nature Conservancy who led the research as a doctoral student at State University of New York College of Environmental Science and Forestry (SUNY-ESF). "These forest ecosystems are in a precarious state because we have disrupted the natural hydrologic processes that these plant species rely upon to support and sustain key life processes."

In California's Mediterranean climate, plants and animals have adapted to rely on precipitation and soil moisture recharge during the rainy winter and spring seasons for reproduction and growth during the typically dry summers. Once soil moisture is exhausted, tree species often found in stream corridors, such as willows, cottonwoods and oaks, typically use deeper groundwater. However, the researchers discovered the story was more complicated.

By analyzing five years of vegetation greenness data from satellite imagery, the authors found that in some cases, these ecosystems were affected by "subsidies of water" delivered via human regulation of rivers, agricultural canals and discharges from wastewater treatment plants. Altered streamside woodlands in the most arid regions of the state stayed greener longer into the dry season and were less responsive to changes in groundwater levels than natural ecosystems.

"Although this seems like a good news story—trees benefit from anthropogenic water management—there is an important caveat," said co-author Michael Singer, a researcher at UC Santa Barbara's Earth Research Institute and a professor at Cardiff University in the United Kingdom. "In channels and canals with severely altered flow regimes, there are few if any opportunities for these trees to spawn new offspring. This means that once these riparian woodlands die off, they will not be replaced through forest succession."

Many of the most-altered stream ecosystems are in California's Central Valley, the state's agricultural hub, which produces a third of the produce for the United States. Following the Gold Rush in the 1850s, massive human settlement led to clearing of 95% of the natural floodplain woodlands across the region. These isolated and restricted riparian, or streamside, forests now provide important habitat for threatened and endangered species like the California red-legged frog, Chinook salmon and Swainson's hawk.

As water is rerouted from rivers into canals to accommodate urbanization and the multibillion-dollar agricultural industry, it creates an artificially stable environment for riparian woodland ecosystems. This encourages a "live fast, die young" community that favors trees that peak and then decline within a few decades. Key ecosystem functions—such as the regeneration of new forest stands and their development over time—are being compromised by the extensive alterations to streamflow and to river channels, which are fixed in place and no longer create new floodplain areas where young trees can establish.

"We call these forests the 'living dead' because the forest floor is devoid of saplings and younger trees that can replace the mature trees when they die," Rohde said. This has repercussions related to habitat for endangered species, biodiversity, carbon sequestration and climate change.

"California is one of the most biodiverse regions in the world, containing more species than the rest of the United States and Canada combined," said Rohde. "In the midst of the sixth mass extinction, the long-term sustainability of California's river ecosystems and the preservation of the rare and endemic species that live within them now rely on the deliberate, coordinated management of resource and government agencies."

This study is part of a $2.5 million suite of projects that the collaborators at SUNY-ESF, UC Santa Barbara and Cardiff University have funded throughout the U.S. Southwest and France. The investigators also include UCSB geography professor Dar Roberts, one of the study's co-authors. The goal is to develop water stress indicators for dryland riparian forest ecosystems threatened by climate change and increasing human water demand.

Rhode and The Nature Conservancy will use the insights from the study to provide scientific guidance to California natural resource agencies for sustainably managing groundwater-dependent ecosystems throughout the state. As Singer pointed out, the findings pertain to the recent sustainable groundwater legislation passed in California. The Sustainable Groundwater Management Act, requires all groundwater stakeholders to agree on sustainability targets for groundwater usage to support urban areas, agriculture, industry and ecology.

The research team used publicly available online data and Google Earth Engine, an open-source tool for analyzing data from satellites and other global spatial datasets. "Our methods and findings open up a whole new world of interdisciplinary research possibilities and ways that water practitioners can consider ecosystem water needs to achieve sustainable water management," Rohde said.

John Stella, a SUNY-ESF professor and principal investigator on the National Science Foundation grant that funded the study, characterized the work as "groundbreaking" for the way it "combined several big datasets in an innovative way to understand how climate and water management interact to put these sensitive ecosystems at risk."

"[The] findings are important for sustainably managing groundwater, not only throughout California, but in water-limited regions worldwide," Stella said. "By creatively harnessing and integrating these large environmental datasets, we can now answer resource management questions at a scale that was previously impossible."

More information: Melissa M. Rohde et al, Groundwater dependence of riparian woodlands and the disrupting effect of anthropogenically altered streamflow, *Proceedings of the National Academy of Sciences* (2021). DOI: 10.1073/pnas.2026453118

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