Even California's Mighty Oaks Are Dying From Drought

Todd Dawson of U.C. Berkeley discusses new research that shows how California's ancient oak trees displayed clear signs of stress as they died from drought – signs that could be useful in the next drought.

About the Author

Matt Weiser

Matt Weiser is a contributing editor at Water Deeply. Contact him at matt@newsdeeply.org or via Twitter at @matt_weiser.

The water supply dropped out from under blue oaks growing on ridges between 2012-2015, including these in San Luis Obispo County, causing widespread tree deaths. Todd Dawson

THE ONGOING CALIFORNIA drought has killed more than 100 million trees, according to a recent U.S. Forest Service estimate. Many of these, it turns out, are very old oaks – trees that are known to be drought resilient and have survived numerous droughts in the past.

So what happened to these oak trees?

Todd Dawson, a biology professor at U.C. Berkeley, and several colleagues investigated that issue at three sites in Central California over the past couple of years. They found that these stately, mature oak trees fell victim to severe groundwater depletion.

In short, even the very deep roots of ancient oak trees could no longer reach the aquifers that have sustained them for centuries. That's because the

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Drought's Alarming Toll on California Forests

rainfall deficits, high temperatures and unprecedented groundwater pumping by urban and agricultural Californians.

Their study also found that the trees showed measurable signs of stress before death. The trees switched to consuming a different type of carbon in their cells, they produced dwarf leaves and some produced no leaves at all. These are all telltale signs that could be used in future droughts to protect oak trees and manage groundwater – if we're willing to pay attention.

Dawson recently spoke with Water Deeply about the study and the future of California's iconic oak landscapes.

It's worth noting, by the way, that the Forest Service survey of 100 million dead trees only covers the Sierra Nevada region. It doesn't include the Central Valley or coastal hills, where millions more trees, including oaks, likely succumbed to the drought.

Water Deeply: What do your results say about the severity of this drought on a historic scale?

Todd Dawson: The 2012-2015 drought was the most severe in the known weather station records

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Todd Dawson, professor of biology at U.C. Berkeley, has studied the loss of oaks during California's drought. (University of California)

recorded weather). And according to tree ring investigations, the drought may be the worst in over 600 years.

Oaks are very resilient to drought. But the groundwater receded below their rooting zone, so they simply died.

The drought was the drought – the cause is unknown – but it was linked to the hottest temperatures in the history of human records, and the velocity of these temperature increases are linked to fossil fuel combustion (there is no doubt about that) that was caused by man. Period.

Water Deeply: And what about the links between groundwater and habitat? Is that a connection we've been blind to, in some ways?

Dawson: During the drought, groundwater recession was massive – the largest I've ever seen. This led to access to these deep water resources being lost by many of our native trees, and this led to mortality. If the groundwater is not restored each rainy season, this will lead to further losses of

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We need to strictly regulate groundwater use. Agriculture in the state has gotten a free ride with pumping this water, yet they are only one place where the water is needed. The over-extraction of this water is killing some of our state's natural resources.

Water Deeply: You showed how some trees produced clearly visible growth changes during this severe drought. Could these observations serve as warning signs during future droughts?

Dawson: Yes, it does seem that the ability of the oaks to make very small leaves is a "early warning" sign that they are running out of water resources. And when this happens, they also fix less carbon and therefore grow smaller leaves.

This response, as well as dropping leaves altogether, is a handy way to "avoid" the stress that comes with drought. But like any response it has its limits as a coping strategy, and it didn't prevent many trees from dying.

Water Deeply: Your study looked at two sites in the Bay Area and one near San Luis Obispo. To what extent can your results be extrapolated to

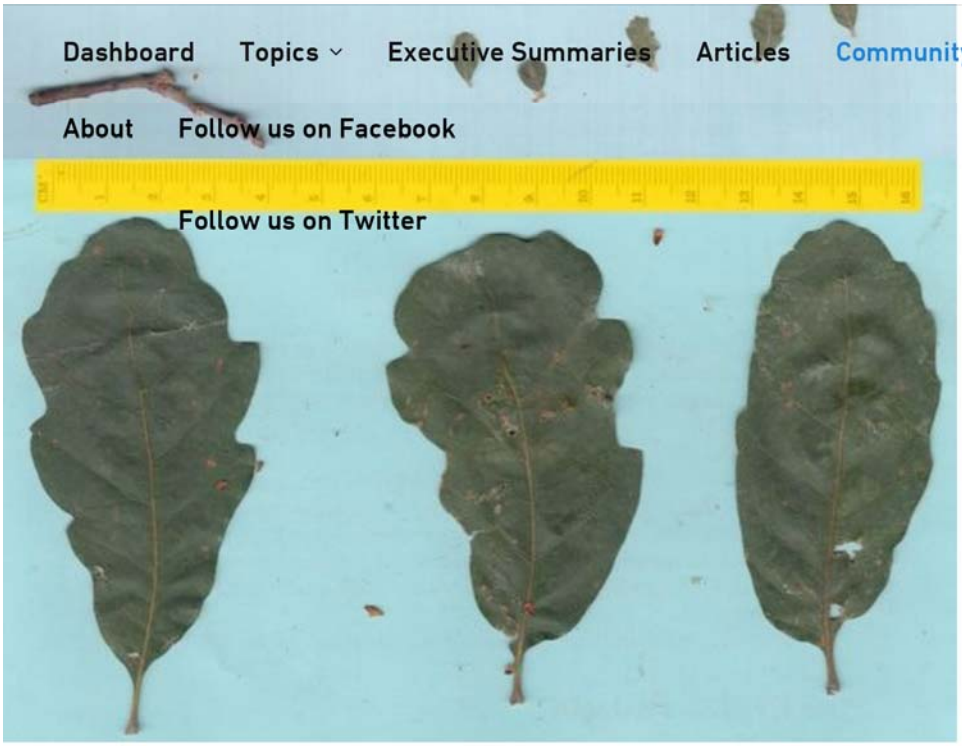
Dawson: Our sites were focused around Central California, but did capture a marked rainfall and temperature gradient that represented a significant fraction of oak woodland systems across the state. With the exception of southern California, which has seen an even more severe drought than central or northern parts of the state, I think what we have seen does provide insights about tree response to drought that goes beyond our sites.

Water Deeply: Will these drought-killed oaks be able to regenerate? Or will we see a permanent shift in the extent of California oak woodlands?

Dawson: Some of the oaks, like blue oak, will not regenerate from existing root stocks. They will have to regenerate from seed if this is possible.

Other oaks, like some of the state's evergreen oaks, may regenerate from resprouting like they can do after fire.

Water Deeply: Blue oaks seemed to be especially vulnerable in this drought, because they tend to grow on hilltops or slopes. What can be done to help them?



Blue oaks stressed by drought produced dwarf leaves (top) that were much smaller than normal, as illustrated in this photo. (Todd Dawson)

Dawson: The blue oaks are dying in the very edges of their range – at the driest southern end and hilltops where they have run out of water. They are also not regenerating from seed, and we don't really know why.

Planting them could help, and it works where it has been tried. It is always a good idea to look at preservation options to protect tracts of habitat and land as key natural resources, for their ecosystem functions and services, and linked them to our rich statewide biodiversity.

Water Deeply: What changes might we

Dawson: Some large oak trees serve as "habitat" trees – places where birds nest, hide, eat, fledge their young. If these habitat trees are lost for species of wildlife like the acorn woodpecker, this will certainly have negative effects on the birds. This may be one impact that is least well understood.

Water Deeply: If our oak population shrinks dramatically, what is likely to replace those trees?

Dawson: Shrubs could replace the trees if conditions remain very dry. And invasive species are on the rise and could also replace many of our native plants, too – trees and shrubs.

There are many invasive woody and herbaceous species from Europe, from Australia and from Africa that could move in. The list is long.

As a result, we could see losses of diversity, increased risk of more losses in species of importance and of ecosystem services.

Water Deeply: How will this change the iconic California landscapes and scenery

Dawson: This is the largest unknown at this time. We really don't have a good idea or model for what these changes will really look like.

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Most Popular Water Deeply Stories of 2016

In case you missed a few favorites, we rounded up some of the popular reads from this year on Water Deeply about the California drought and water issues in the West.

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Firefighters battle the Bluecut Fire along Swarthout Canyon Road in the Cajon Pass, north of San Bernardino, Calif., Tuesday, Aug. 16, 2016. Will Lester/The Sun via AP

THIS YEAR, WE continued to dive deeply into California water issues, covering legislative battles,

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About the Author

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Of the hundreds of stories, interviews and op-eds we published, here are some reader favorites.

What Lake Mead's Record Low Means for California

by Michael Levitin

When the U.S. Bureau of Reclamation announced last month that the country's largest reservoir, Lake Mead, had fallen to its lowest-ever level at 1,074ft (327m), the question many asked was: How will it affect one of California's primary drinking sources?

After all, some 19 million Californians, nearly half the state's population, receive some part of their water from the Colorado River, which flows into the 80-year-old reservoir created by Hoover Dam outside Las Vegas. READ THE REST

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are projected to increase dramatically with anthropogenic warming.

That's the general consensus among scientists studying the relationship between fire activity and climate change in the Sierra Nevada. But a study released last week found an influence on past fire activity even greater than climate: human beings. READ THE REST

'The Blob' Is Back: What Warm Ocean Mass Means for Weather, Wildlife

by Matt Weiser

The blob is back.

Since 2014, a mass of unusually warm water has hovered and swelled in the Pacific Ocean off the West Coast of North America, playing havoc with marine wildlife, water quality and the regional weather.

Earlier this year, weather and oceanography experts thought it was waning. But no: The Blob came back, and it is again in position off the coast, threatening to smother normal coastal weather and ecosystem behavior. READ THE REST

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by Alastair Bland

Water, or the lack of it, has emerged as one of the greatest sources of stress for California, its people and its native species. Fish populations are declining in the Sacramento-San Joaquin Delta, while farmers are facing short supplies. Urban dwellers have come under pressure to use less water, and underground reserves are being rapidly depleted. Making matters much worse is the ongoing drought, which shows no sign of ending. In fact, forecasts for less annual rainfall in years to come have cast uncertainty on the very future of California and its rapidly growing human population.

But state officials have proposed a solution – a massive hydroengineering project dubbed California WaterFix. Its two giant tunnels will divert water from the Sacramento River toward Silicon Valley, Los Angeles and farms in the San Joaquin Valley. READ THE REST

Peter Gleick: Why California's Current Drought Is Different

by Tara Lohan

In 1987, California was at the beginning of what

the state's history. Fittingly, that same year Peter Gleick helped to co-found the Pacific Institute, a global think tank that would become a leader in global environmental and California water issues.

In 1987, Gleick had just finished a doctorate from the University of California, Berkeley, in the Energy & Resources Group, where his dissertation was the first to study the impact of climate change on water resources. Eager to use his background in climate science and hydrology in a multidisciplinary endeavor, he and graduate school colleagues launched the Pacific Institute, turning a $37,000 grant into an internationally recognized research institute that has just celebrated 29 years in existence. READ THE REST

Bear River: The Biggest Dam Project You've Never Heard Of

by Matt Weiser

Utah's Bear River is an odd creature. Its headwaters and its mouth are only 90 miles (145km) apart. But the river takes its time spanning those points, flowing 500 miles over a tortuous path.

It begins high in Utah's Uinta Mountains, then spills north into Wyoming and Idaho, looping around the Wasatch Mountains. Near the town of

turn and then flows south, down the other side of the Wasatch and back into Utah, where it dumps into the Great Salt Lake. READ THE REST

The Drought Solution That's Under Our Feet

by Padma Nagappan

Now in the fifth year of an epic drought, Californians have explored ways to save water and wring it out of typical and atypical sources. The search has spanned the gamut from funding research, investing in expensive solutions like desalination plants, toying with the idea of recycling wastewater, imposing water-use restrictions, letting lawns go dry and experimenting with irrigation efficiency techniques for the crops that feed the country.

Thirsty crops, a burgeoning population and below-average precipitation have also led to seriously overdrawn groundwater sources that took a very long time to fill up. The state's agricultural industry, which grows more than 250 crops, has also been vilified for its heavy water use. READ THE REST

Legislative Update: Six New California

Mike Stearns, chairman of the San Luis and Delta-Mendota Water Authority, checks the soil moisture on land he manages near Firebaugh, Calif. (Rich Pedroncelli, AP)

The end of September meant both the end of the 2016 water year and a deadline for signing new legislation. In the past few weeks California Gov. Jerry Brown has signed a bevy of new bills into law, many of them addressing drought or water issues in the state.

Some affect water indirectly. Senate Bill (SB) 859, which establishes a Healthy Soils Program, is written to help build quality agricultural soil to increase carbon sequestration, but healthy soils also help retain more water. SB 1414 aims to help increase energy efficiency, which can also help save water. READ THE REST ■

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LAW & POLICY OP-EDS

How Scott Pruitt May Impact Air and Water Protections as Head of

Is Trump's prospective new head of the Environmental Protective Agency truly like putting "an arsonist in charge of fighting fires"? Law professor Robert Percival looks at Scott Pruitt's track record as Oklahoma attorney general to see what impact he may have.

WRITTEN BY
Robert Percival, The Conversation

PUBLISHED ON
Dec. 29, 2016

READ TIME
Approx. 6 minutes

Oklahoma attorney general Scott Pruitt arrives at Trump Tower in New York, on December 7, 2016. Andrew Harnik, AP

DONALD TRUMP'S ELECTION has jolted environmentalists and voters who care about conservation. Trump has called for abolishing or

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About the Author

Robert Percival, The Conversation
PROFESSOR OF ENVIRONMENTAL LAW, UNIVERSITY OF MARYLAND, BALTIMORE

Robert Percival is professor of environmental law at the University of Maryland, Baltimore.

Agency (EPA), declared climate change a Chinese hoax and promised to "cancel" the Paris climate agreement.

Though Trump appears to have backed off his pledge to "get rid of [EPA] in almost every form," his choice of Oklahoma attorney general Scott Pruitt to head the agency set off alarms in the environmental community.

Environmentalists were quick to denounce Pruitt, calling him an opponent of EPA who built his reputation by doing the bidding of fossil fuel industries. Is his appointment really like putting "an arsonist in charge of fighting fires," as the Sierra Club argues?

Pruitt's Anti-EPA Legal Activism: Many Lawsuits, Few Wins

A close look at Pruitt's record reveals that he is a very smart, charismatic lawyer and passionate baseball fan who professes to care about protecting the environment. But his swift rise to national prominence was built on anti-EPA legal activism. Since his election as Oklahoma's attorney general in 2010, Pruitt has repeatedly brought lawsuits claiming that EPA is illegally and unconstitutionally trampling states' rights. These

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but little success in court.

Pruitt's signature legal issue was his fight to block EPA from requiring coal-fired power plants in Oklahoma to install scrubbers to reduce pollution that impaired air quality in national parks. Pruitt's legal arguments were rejected in 2013 by the U.S. Court of Appeals for the Tenth Circuit, which ruled in favor of EPA, a decision the U.S. Supreme Court deemed unworthy of review.

Pruitt has repeatedly joined other Republican attorney generals in litigation against the Obama administration. In two cases, the Supreme Court ruled against their efforts to strike down the Affordable Care Act.

Pruitt has also sued other states. When he sought to invoke the Supreme Court's original jurisdiction to claim that Colorado had created an interstate nuisance by legalizing recreational use of marijuana, he was quickly tossed out of court.

In 2012, Pruitt and I testified on opposing sides at a congressional hearing. Pruitt's congressional allies held the hearing to accuse the Obama administration of conspiring with environmentalists to settle litigation on terms unreasonably favorable to the environment. I described such claims as fanciful, but later a

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Times revealed that Pruitt had allowed an oil company to ghostwrite documents he sent to EPA. Pruitt's defense was that he agreed with what the oil company had written.

On climate change, Pruitt has contended that the science is too uncertain, and that the United States should not act because China will never agree to control its emissions. Both claims are demonstrably false, especially in light of China's recent commitments under the Paris climate agreement. Pruitt joined the state of Texas in asking the Supreme Court to overrule its landmark decision holding that the Clean Air Act gives EPA authority to regulate greenhouse gases. The court refused.

Pruitt joined other states in suing to block EPA's Clean Power Plan – the Obama administration's signature rule to control emissions of greenhouse gases from existing power plants – a year before it even was issued. When the case was filed, my students unanimously predicted that it would be dismissed for violating a bedrock principle of administrative law: Only final agency action can be challenged in court. It was dismissed on precisely those grounds, but Pruitt has now sued again to challenge EPA's final rule.

How would Pruitt change EPA? Clearly, given his record of fighting federal authority, states will have much greater leeway in their dealings with the agency. Pruitt wants to repeal the Clean Power Plan and EPA's "Waters of the United States" rule, which seeks to clarify the limits of federal jurisdiction to protect wetlands. Both rules have been finalized and face court challenges from Pruitt and others.

Before adopting the rules, EPA was required by the Administrative Procedure Act to provide the public with notice and an opportunity to comment. EPA promulgated the Clean Power Plan only after considering 4.3 million public comments, the most the agency has received during its 46-year history. The water rule was adopted only after EPA reviewed 1 million public comments and more than 1,000 scientific studies. Once rules are finalized, persons affected by them can ask a court to overturn them if they are not consistent with law or insufficiently supported by evidence.

After taking office, the Trump administration likely will announce that it no longer will defend the Clean Power Plan and the waters rule in court. But some states and NGOs have intervened to defend the rules, so litigation will continue. If courts

or illegally when it adopted the rules, as Pruitt has claimed, they will strike the rules down.

But if Pruitt loses again and the rules are upheld, EPA will have to repeal them through the same notice-and-comment process it used to adopt them, as Pruitt has acknowledged. This will take considerable time.

To survive judicial review, EPA under Pruitt will have to articulate good reasons for repealing the regulations. When the incoming Reagan administration sought to repeal a rule requiring air bags on new cars in the early 1980s, the Supreme Court rejected the action as "arbitrary and capricious" because the evidence before the agency clearly supported the regulation. As a result, countless lives have been saved.

Pruitt might even try to take a radical step and reverse EPA's 2009 finding that greenhouse gases endanger public health and welfare. This approach is so clearly contrary to the weight of scientific evidence that it is doubtful it would survive judicial review. In 2011, when it reaffirmed that the Clean Air Act covers greenhouse gases, the Supreme Court cautioned that any EPA decision not to regulate them would be subject to judicial review and could be overturned if it was found to be arbitrary and capricious.

could repeal the Clean Power Plan and waters rule, because agencies have significant discretion in deciding to how to carry out the law. But as with President-elect Trump's pledge to repeal the Affordable Care Act, the crucial question then will be what replaces them. If EPA's finding that greenhouse gases endanger public health and welfare stands, then EPA has an obligation under the Clean Air Act to control them. What approach will Pruitt use to do so?

The same question applies to the water rule. Pruitt has called this measure "a classic case of overreach," but the rule simply clarifies pre-existing limits on federal jurisdiction under the Clean Water Act. A decade ago, the Supreme Court split 4-1-4 on this issue, creating enormous confusion that persists today. EPA based its rule on extensive study of how pollution affects various water bodies. Pruitt can either reinstate this confusion or try to revisit the science in a new rule-making.

As a longtime resident of Washington, D.C., I have no elected representative who will have a vote on Pruitt's confirmation. But I hope that after he arrives in town his love of baseball will take him to Nationals Park, where he will discover a "politics-free" zone. As the new federal guardian of the

politics-free" zone devoted to environmental protection. But his track record of devotion to fossil fuel interests and hostility toward EPA make that prospect unlikely. Pruitt may find it easier to take apart EPA rules from the inside than his experience on the outside.

This article was originally published on The Conversation. Read the original article.

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The Seven Key Things That Happened in California Water in 2016

The drought continues to impact California economically, politically and ecologically. Here's a look at the most significant recent developments that will shape the year ahead.

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Tara Lohan	Dec. 28, 2016	Approx. 5 minutes

About the Author:

Tara Lohan

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A buoy lies high and dry above the water line at the now defunct Echo Bay Marina in the Lake Mead National Recreation Area, near Las Vegas, May 2016. Lake Mead's surface was at its lowest level since the reservoir was created. John Locher, AP

THIS YEAR HAS been a big one for water. California is still mired in drought, although less of the state is suffering than in previous years and each winter rainstorm brings a fresh bit of optimism.

A large reserve of groundwater was found deep under the drought-stricken Central Valley, recycled water continues to gain in popularity, flooding to help fish and farmers is panning out and 2016 will likely wrap up as the hottest year on record.

Below are seven other significant milestones that impacted California water and will help shape the year ahead.

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would lift California out of drought didn't live up to expectations. And what precipitation did come was concentrated much more heavily in the northern parts of the state, leaving Southern California high and dry.

By mid-April, while snowpack was at 100 percent of average in parts of the northern Sierra Nevada, precipitation in Los Angeles was at only 58 percent. And the snowpack reading for the southern Sierra Nevada on April 1 was 65 percent of average.

To make matters worse, despite normal wet weather in the north, warmer temperatures meant that by May 1 the snowpack statewide dropped to only 55 percent of average – a marked improvement over the historically low snowpack of 2015, but nothing close to what the state needed to make a big impact on the drought.

2. Conservation Mandate Ends

After nearly a year of Californians rising to the challenge of a 25 percent statewide conservation mandate, the policy was disbanded in May. The State Water Resources Control Board changed course and instead decided to let water agencies set their own conservation standards.

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process in which individual water districts will forecast their demand and supply for the next three years, assuming continued below-average precipitation," the Sacramento Bee reported. "Districts would be required to reduce water use by an amount equal to their projected shortfall."

Following the decision, most water agencies set conservation goals at or near zero, and conservation statewide fell.

3. Diminishing Lake Mead

In June, Lake Mead hit its lowest point ever since the reservoir on the Colorado River was built 80 years ago. Around 19 million Californians, nearly half the state, get some portion of their drinking water from the Colorado River.

The Bureau of Reclamation believes the lake's shortage will be so low by 2018 it will not be able to make its deliveries to lower-basin states Nevada, Arizona and California. The three states have been working for months on a compromise, should the shortage warrant it.

However, in December the Las Vegas Journal-Review reported a new hitch – trouble in California is holding things up. "Before they agree to store more water in Lake Mead, California's largest river

have to forgo to protect endangered fish in the Sacramento-San Joaquin Delta or keep the Salton Sea from drying up, triggering an ecological disaster," the Journal-Review reported.

4. Toxic Algae Outbreaks

An algae bloom in the reservoir behind Iron Gate Dam on the Klamath River near Hornbrook, California. (Jeff Barnard, AP)

The summer was marked by several outbreaks of toxic algae blooms in waters across the state, fueled by low water flows, warm temperatures and high levels of nutrients. Although toxic algae blooms happened in both Northern and Southern California, of particular concern was the Sacramento-San Joaquin Delta.

"In the Delta, it's important to us because we have

protecting the water quality is of huge ecological importance," Peggy Lehman, a staff environmental scientist at the California Department of Water Resources, told Water Deeply. "With the State Water Project drawing from the Delta, we have to take a look at the importance of anything like this because it could be quite detrimental to human health and water quality."

5. Tree Mortality on the Rise

One of the most visible signs of California's drought has been patches of red amid the typically green hillsides of California's conifer forests in the Sierra Nevada. Recent aerial surveys indicate that the number of dead trees, thanks to drought and beetles, has risen to 102 million, with more than half dying in the last year.

"The scale of die-off in California is unprecedented in our modern history," Randy Moore, forester for the region of the U.S. Forest Service that includes California, told the Los Angeles Times.

While statewide surveys have been conducted in the Sierra Nevada, smaller-scale research in coastal areas has also found that usually resilient oak trees are also dying from drought as tree roots can no longer reach falling aquifers.

In December, President Obama signed the Water Infrastructure Improvements for the Nation Act, a $12 billion measure that provides aid for Flint, Michigan, and projects to fund dams and provide flood protection across the country. Stuffed into the legislation were controversial provisions that will affect how much water is pumped out of the Sacramento-San Joaquin Delta.

Michael Doyle, reporting for McClatchy, called it "the biggest federal reset of California water use in a generation, setting the stage for easier dam-building, more recycling and potentially happier Central Valley farmers."

The new law has received cheers from San Joaquin Valley farmers and jeers from the environmental community and Delta-area residents worried about overpumping from the environmentally sensitive Bay Delta. The law calls for pumps "to maximize water supplies for the Central Valley Project and the State Water Project," and may run into conflict with provisions in the Endangered Species Act that limit pumping at certain times to protect endangered fish species.

7. Delta Tunnels Inch Forward

California took another step forward on California WaterFix, the plan to build twin tunnels in the Delta, by releasing more than 90,000 pages of a finalized environmental impact report.

Erin Mellon, a spokeswoman for the state's Natural Resources Agency, told the Sacramento Bee that the state hopes "to have federal permits approved next year and construction under way as early as 2018." The report comes after "hundreds of public meetings and thousands of comments," according to the Natural Resources Agency.

"After years of scientific study and analysis, we have found the best solution for protecting both the Delta's ecosystem and a vital water supply for California," said Mark Cowin, director of the California Department of Water Resources.

But Restore the Delta, one of the most outspoken critics of the plan, released a statement saying that the document "is not a green light for the Delta Tunnels but rather should be understood as the submission of homework by sponsoring agencies ... to be evaluated by state and federal regulators who will determine if proposal can meet environmental and water quality standards ... A feat no previous version of the proposal has achieved."

The project still faces other hurdles, including

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Q&A

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Humans Are Missing in

A huge habitat restoration is being planned in the California Delta, and you'd hardly know there are people involved. In a new study, Brett Milligan argues that humans have to be given their proper role in the process.

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Matt Weiser	Dec. 27, 2016	Approx. 7 minutes

Fishermen try their luck from a water intake structure along the Sacramento River in the Sacramento-San Joaquin Delta, near Courtland, Calif. U.C. Davis professor Brett Milligan argues in a new study that recreation and other human uses have been neglected in Delta restoration efforts. Rich Pedroncelli, Associated Press

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constant change, affected by daily tides, sea-level rise, water diversions that serve 25 million residents and a growing population closing in around it.

Yet most of those people have no idea the Delta is the subject of one of the largest habitat restoration projects ever proposed in the U.S. Known as Eco Restore, it is a companion to another proposal called California WaterFix, which calls for reforming water diversions by building two giant tunnels.

Brett Milligan, U.C. Davis assistant professor of landscape architecture, co-authored a new study looking at human impacts in the Delta. (Brett Milligan)

In a new study, Brett Milligan, assistant professor of landscape architecture at U.C. Davis, argues that human uses of the Delta have become an afterthought in these two enormous planning efforts. Furthermore, Milligan and his co-author, PhD candidate Alejo Kraus-Polk, contend that the success of both efforts will be far more likely if they change focus now to make people an integral part of the process.

Water Deeply recently spoke with Milligan to learn

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cals, pesticides and other toxins.

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Water Deeply: How did this study come about?

Brett Milligan: It generally grew out of working with other researchers in the Delta. I'm from a design background myself – landscape architecture – and realized there was a human component to these restoration projects. And for the most part, it seemed like people were not talking about that. It wasn't something that was in the foreground in any way.

Water Deeply: You note a "considerable void" in integrating human factors in Delta restoration activities. Can you elaborate?

Milligan: The one part that is discussed is recreation. And that's OK. But often that's just a very prescriptive set of ways that people interact with the Delta: boating or hiking or kayaking. But that doesn't cover all the things that are happening out there.

We make the point in our report that it's cost effective to include human uses, and if they're properly planned, it saves money. But these things are often considered outside the scope of projects. They're seen as not integral to the restoration.

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Appropriate is an interesting term. I think it's counter to a lot of the objectives of restoration work, particularly in a context such as the Delta, where you have a very unique cultural heritage there. You have a high degree of urbanization surrounding these projects. When people are occupying these landscapes in ways that are not planned for or guided, they tend to have a detrimental effect on some of these projects.

Water Deeply: How can including human uses of the landscape save money on restoration activities?

Milligan: There are a variety of ways. One of them that we point out is citizen science. It brings more eyes on to the landscape, which might bring more favorable uses on to the landscape.

Planning for human uses at the outset, it's much more cost effective because then you don't have to go back and rebuild to accommodate it later. If later you want to bring in recreation, you typically have to mitigate for that, which makes things much more expensive.

Another thing we mentioned in the report is that scientists all know the Delta has novel ecology. It's forming so fast and it's a very dynamic place. But

toward tourism, recreation and cultural aspects of the Delta, and totally shuns all that dialogue about the novel ecology and the kind of challenges we're faced with. We argue that [this] should be really brought to the fore, so people really know what the Delta is about.

A family strolls along rows of grape vines in a field near Clarksburg, Calif., one of the communities likely to be affected by habitat restoration plans. (Rich Pedroncelli, Associated Press)

Water Deeply: You talk a lot about the need for ecosystem reconciliation in the Delta. Can you explain what you mean by that?

Milligan: The basic idea is that, rather than separate out these ideas that are just for other-than-human things, we have to reconcile ourselves within these landscapes that we are trying to

this type of separation, because of the magnitude of how much we have altered habitats and things across the Earth, it's the idea of trying to bring some of this into the landscapes we inhabit.

Water Deeply: Is this being practiced by those planning the Delta's restoration?

Milligan: I think it's very much caught on in the scientific community. I think it's particularly appropriate in the Delta, where it's very clear the Delta is never going to go back where it was (historically). It's an impossibility, based on the degree of transformation. But it's still not really clear how it's going to be practiced or moved forward, in terms of how that reconciliation actually happens.

Water Deeply: You refer to some restored landscapes in the Delta as "feral." What do you mean by that?

Milligan: Feral generally means kind of removed from domestication. If you look at the Delta, I think it was 98 percent domesticated in terms of what reclamation did to all those wetlands. So restoration in the Delta, whether it happens deliberately or not, is really taking these landscapes from a domesticated state into a

But in the Delta, we have two types of restoration: naturalized or restored. A naturalized landscape is the more feral version, something like Franks Tract or Big Break, which are these accidentally rewilded landscapes that happened through accidents like levee breaks. Versus something that is a restored landscape, where the effort is intentional – something like McCormack-Williamson Tract, which has been in the works for 20 years and is still yet to happen.

If more levee breaches happen, we'll have more of these feral landscapes, where we'll be dealing with a largely novel ecology. Another great example is Liberty Island. When Liberty Island breached, it was sort of just let go. Nobody was really managing it. At first, duck hunters pretty much took over that area.

It's debatable, but I think there has always been a sort of feral quality to the Delta – sort of the bayou of the West – where people went to get off the grid and escape. Some of that is due to the waterways. There's nowhere else in the country that has this kind of maze of waterways and a low density of habitation within there.

Water Deeply: What are the risks if these

Milligan: I think the biggest risk is, if there isn't community buy-in on the restoration projects, then oftentimes they're seen as an imposition rather than a type of amenity for the community. Those projects that have a good connection with the local community really increase their rate of success, because you have those communities looking out for those projects. If restoration is imposed, it plays itself out where it can get sabotaged, and there isn't support for it.

I think most of the scientific community is aware of this now. I'm not sure it has been put in a set of best practices yet. But I think that has come to light through trial and error.

Water Deeply: What advice do you have for those who are planning Delta restoration projects?

Milligan: The biggest thing is, we don't really have a champion, or someone who is really looking at integrating human uses at a senior level. I think a lot of the human-use stuff sort of gets subcontracted elsewhere. It's not in the central discussion. I think bringing somebody in who could actually integrate how science is working with other users could help forward science or restoration efforts.

terms of human uses. Again, if you compare that to the Bay, it's mandated. But it's just sort of recommended in the Delta plan. I think there's room there to make more robust planning regimes to make human uses more of a focus.

Water Deeply: You also write that restoration of the Delta is likely to create landscapes that are "unprecedented." What do you mean by that?

Milligan: All deltas are very dynamic. You can see these huge changes that have happened in a very short time that have transformed the Delta over and over. Some people wonder if we're at a tipping point. With sea level rise, are we going to see more levees overtopped, is the Bay going to move into the Delta or are we going to radically alter how water moves through the Delta through underground pipes?

It just seems like we're on a precipice of more radical changes happening throughout the Delta to create yet another new Delta.

There's this really interesting notion of the Delta as an evolving place, which I think nobody has really figured out what to do with. Because the Delta changes so fast, it's not something that human societies are adept at dealing with. We sort

Delta has never offered that. So the type of conditions that people encountered when they settled in the Delta are very different from what we face today.

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