In the Sierras, New Approaches to Protecting Forests Under Stress

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Giant sequoias in Sequoia National Park. Tuxyso/Wikimedia

By Janet Marinelli

In California's Sierras and around the world, extreme drought and rising temperatures are killing trees and threatening the viability of forests. Some ecologists are saying that land managers now need to adopt radically new strategies.

"The clearest way to the Universe is through a forest wilderness," declared John Muir, whose belief in the necessity of untrammeled and enduring nature became the bedrock of contemporary conservation. No forests inspired Muir more than those blanketing the Sierra Nevada, "miles in height, and so gloriously colored and so radiant, it seemed not clothed in light but wholly composed of it, like the wall of some celestial city."

Today, the forests of Muir's "Range of Light" and their celebrated woody inhabitants are pitted against the 21st century's version of the Four Horsemen of the Apocalypse — heat waves, extreme droughts, insect plagues, and massive wildfires — all linked to climate change. Some giant sequoias, the range's most iconic conifers, suffered a sudden leaf dieback in 2014 as about half of their needles turned brown and fell to the ground. In Sequoia National Park, more than 70 percent of the big sugar pines and 50 percent of the large ponderosa pines growing in lower-elevation forests have been decimated by bark beetles. The U.S. Forest Service announced in November that an additional 36 million trees across California had died since its previous aerial survey just six months earlier, bringing the total number of dead trees since 2010 to more than 102 million.

The problem extends far beyond California. Writing in *Science* magazine in 2015, ecologists Constance Millar of the U.S. Forest Service and Nathan Stephenson of the U.S. Geological Survey concluded that extreme drought, exacerbated by rising temperatures and other megadisturbances, is pushing temperate forests in Europe, South America, and Australia, as well as the American Southwest "toward and over resilience thresholds," with little prospect of returning to conditions of the recent past.

At a time when restoration of forests and other ecosystems is increasingly essential, the dominant paradigm of restoration science has been shaken to its core. Restoration ecologists, for whom returning lands to their state before the arrival of Europeans on the continent is still the basic, if rarely stated, goal, have been at loggerheads with so-called new ecologists, who challenge the primacy of native species in conservation thinking and champion the "novel ecosystems" of native and exotic species that increasingly dominate the planet.

But the controversy begs the questions: What do we do with declining forests in the Sierra Nevada and around the world? And how do we secure the future of the sequoia and other native species that have inhabited them for millennia?

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To preserve the native biodiversity that could otherwise be lost, Millar, Stephenson, and other researchers have been encouraging federal land managers to employ a "toolbox" approach and hedge their bets with a combination of "resistance," "resilience," and "realignment" actions. Some resistance and resilience measures have been used by managers for years to reduce the massive fuel loads that have accumulated due to decades of fire suppression, and they are now being redirected toward helping forests withstand rapid climate change. One of the most important is forest thinning, a process in which small trees and brush are removed, either mechanically or through controlled burning. Thinning not only reduces a forest's potential flammability but also its drought stress by decreasing competition for water and soil nutrients among the trees that remain. However, the need for such efforts is so vast, scientists note, that land managers must perform triage, deciding where in the landscape to ration their limited funds.

Millar likens resistance and resilience efforts to the story of the Little Dutch Boy who plugged a hole in a dike with his finger. "At some point," she says, "the pressure is going to be so hard that you just can't keep holding your finger there." These actions can, however, help buy time while researchers and managers seek the best options for realignment, in which they actively facilitate changes being driven by rapidly shifting conditions to help forests and species adapt.

Aerial view showing dead trees in Sequoia National Forest in August 2016. US Forest Service

Global warming is making the longtime habitat of many trees increasingly inhospitable, for example, while moving the climate conditions for which they evolved to a different place. So as a first step, realignment could include moving climate-stressed populations into more suitable areas within the species' native range. But computer modeling suggests that livable conditions for some species, including the sequoia, may disappear in their native range by the end of the century. This may make it necessary to establish "neo-native" populations of these trees, located well outside their present boundaries but within the range found in the fossil record — a process called assisted migration. Although physical realignment of trees to track changing conditions is already underway in commercial forestry, where maintaining peak productivity is the primary concern, the notion is almost antithetical to the hands-off approach of most wilderness proponents.

The fossil record suggests that the Sierras' trees and forests have managed to realign with natural climate changes for the past 2.6 million years, since the dawn of the current Quaternary period. "The end of the golden era of restoration ecology in the 1980s and 1990s led to the abandonment of looking at history [for guidance]. That's too bad," says Millar, who for the past few decades has studied the effects of climate change on ancient bristlecone pines and other weather-battered trees high in the Sierra Nevada and Great Basin ranges. As practitioners of the emerging field of conservation paleobiology, Millar and other paleoecologists use information from fossils, tree rings, sediments, and ice cores to address current conservation problems. Cornell paleoecologist Gregory Dietl has described this new science as "putting the dead to work" to help sustain the diversity of life in the 21st century.

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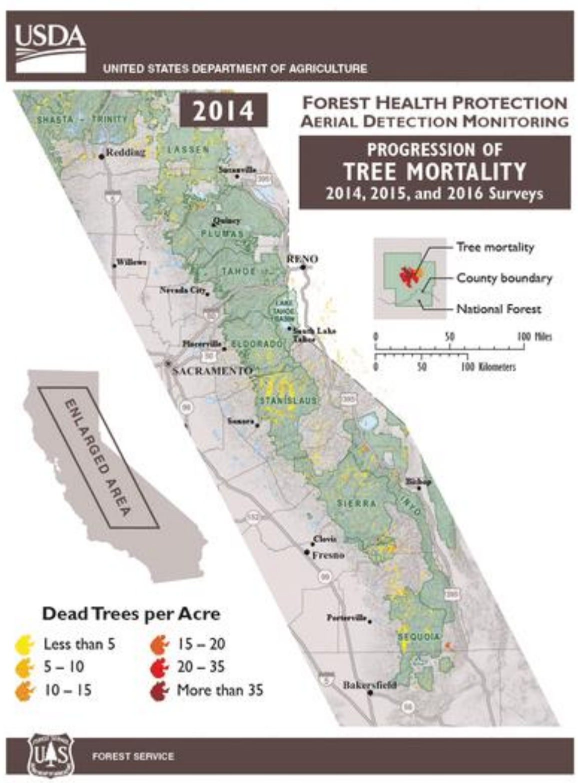
One paleoecological discovery in particular has spurred the current paradigm shift from traditional restoration to realignment. By piecing together evidence in pollen and leaf fossils gleaned from far-flung sites, paleoecologists found that plant ranges do not stay put, as ecologists long maintained and the public continues to believe. During the Quaternary, a veritable climate yoyo that has included some 50 major shifts from ice ages to warm interglacial conditions, the "native ranges" of the Sierras' trees, in Millar's words, "have moved around like heck." While overall plant diversity in the Sierra Nevada has changed little, not only have tree distributions boomeranged around, with each species moving at its own pace, but the number of populations and individuals has seesawed dramatically.

Since the last ice age alone, for example, the sequoia's native habitat has undergone dramatic shifts. Today, the species is restricted to a tiny area of California, in small and disjunct groves between 4,600 and 7,000 feet on the west side of the Sierra Nevada. But the [pollen record suggests] that during the last ice age it may have grown on the opposite side of the Sierras. There is also evidence on the western slope that sequoias grew below 3,400 feet during the last glacial advance and at almost 9,400 feet as the climate warmed about 10,000 years ago — both well below and above the tree's current elevation limits.

While paleoecology indicates that plant species have been able to persist by tracking favorable environments, it also suggests there are limits to species' abilities to cope. The sequoia may have been near extinction during the Altithermal period,which occurred 9,000 to 5,000 years ago. The U.S. Geological Survey's Stephenson, a leading expert on sequoias who has been based at Sequoia National Park for more than 35 years, says the fossil record from earlier eras "tells us one thing — warmer climates are not good for sequoias." Yet in the coming decades, temperatures are expected to spike well above those experienced in the Altithermal, severely testing the adaptation limits of the Sierras' magnificent conifers.



The sequoia, which can use 500 to 800 gallons of water every day during summer, is already responding to the historic drought of recent years. According to Stephenson, who discovered the sequoia dieback, preliminary studies suggest that "dropping their older leaves and keeping the younger, more productive ones was a smart way to adjust to a drought." Researchers and land managers are doing their part to help the species adapt. They are creating a "vulnerability map" that will reveal which sequoia stands are most vulnerable to drought and therefore in greatest need of resistance and resilience actions such as controlled burning and mechanical thinning to reduce competition for water. They are even keeping irrigation in their back pocket as a potential management tactic, although given the arboreal giant's enormous water needs, this could only be employed in small areas.

From a paleoecological perspective, the massive tree mortality in the Sierras' lower elevations, like the sequoia dieback, can be viewed as the forest's attempt to adapt to changing conditions. As a precedent, Millar points to the warmer temperatures of the Medieval Climate Anomaly, from roughly 900 to 1350, which also led to natural forest thinning. "We've been trying to do the same thing with our forest management, only at a much smaller scale," says Millar. "Now nature has done this for us."

Restoring these forests according to the pre-European settlement model would involve replanting the lost ponderosa pines, which became established during the Little Ice Age, from about 1400 to the mid-1800s, when temperatures were some 3.6 degrees Fahrenheit cooler than they are today. But a denser forest full of maladapted trees would increase the risk of the kind of catastrophic change that forest managers fear most — a conflagration that kills everything in sight, not just selective trees, and denudes the slopes, incinerates the top soil and its seed bank, and leads to massive erosion, leaving the land barren and potentially unproductive for centuries.

In contrast, realignment aims to reduce the risk of catastrophic change by easing the transition to a better-adapted forest. One of the reigning assumptions of contemporary conservation has been that local plant populations are best suited to the conditions on a particular site. But at a time of rapid climate change, local is not always best, and one option for realigning lower-elevation forests is replanting areas with so-called genotypes of some of the existing tree species that originate in drier areas, a process known as "assisted population transfer."

To ensure that the tree seed used in forest plantations and restoration projects best matches the conditions at the planting site, a system of "seed zones" and "seed transfer guidelines" has long been in place. British Columbia's Ministry of Forests, Lands, and Natural Resource Operations, a pioneer in the field of adaptation, has facilitated assisted population transfer by updating its system to account for current and projected climate change. The province's standards that restricted the upward movement of tree seed were amended to extend the limit by up to 656 feet to account for recent and future warming.

In the Sierras, Millar says, if massive tree mortality "continues to accelerate and sweeps up the west slope" in the decades to come," even stronger medicine may be necessary. This could include assisted migration of species unable to keep pace with rapidly changing conditions on their own.

Dead conifer needles in the Sierra National Forest in April 2016. US Forest Service

To safeguard the sequoia's future, Sierra Pacific Industries, with the help of federal and state agencies, is already implementing a plan to extend the species' current range by creating neo-native populations on private lands in the Sierra Nevada as well as the Cascade and Klamath mountains farther north. For many conservationists, however, assisted migration as a means of rescuing species threatened by climate change remains controversial. In Sequoia National Park, Stephenson hopes to proceed by "baby steps," identifying locations not far from the current groves where the species is most likely to do well under warming conditions, then proceeding with small-scale assisted migration experiments.

Still, old habits die hard. Stephenson recalls that in the mid-1990s his colleagues in Sequoia and Kings Canyon national parks "probably had the best controlled-burn program in the country." It suddenly hit him, however, that even they were burning just a small fraction of the forest that would have been thinned naturally by wildfires. "I realized that no matter how hard we try, we're not going to make it back" to pre-settlement conditions, he says. In a 2014 essay, Stephenson described how this epiphany triggered "a multi-year period of moderate despair — even depression" about the viability of the National Park Service mission to preserve a semblance of Muir's wilderness — an identity crisis from which many land managers are still reeling today.

From the end of the last ice age to now, the global climate has warmed some 7.2 to 12.6 degrees F, and earth could undergo additional warming of comparable magnitude by as early as the end of this century. "But even with normal change," notes Millar, "ecology is really hard to predict." Throw in the ecological wild cards currently facing forests — from exotic plants and animals interacting with natives in novel ways, to habitat fragmentation that stops migrating species dead in their tracks — and one thing is certain: Forests and their human caretakers are in for a wild ride.

Correction, February 14, 2016: *An earlier version of this article incorrectly stated that sequoias may have been near extinction during the Medieval Climate Anomaly, lasting from 900 to 1350. It should have referred to the Altithermal, which occurred 9,000 to 5,000 years ago.*