Science Update

INSIDE

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The Mighty Oak Faces Challenges in the Pacific West

In popular imagination, the oak tree stands for strength, endurance, and longevity. But in the coastal lowlands and central valleys of British Columbia, Washington, Oregon, and California, oaks face a battery of natural and human-induced threats. Sudden oak death, caused by a virulent pathogen identified in 2000, has killed millions of tanoaks, California black oaks, and coast live oaks in California and southern Oregon. In 2008, scientists linked oak deaths in San Diego County to the newly named goldspotted oak borer, an insect first detected in the state in 2004. Over the years, much of the oak landscape along the west coast has been converted to residential and agricultural uses. Where it remains in Washington and Oregon, the sun-loving oak is threatened by encroachment of other trees. In California's Central Valley, blue and valley oak communities are experiencing insufficient regeneration to match the current population.

Most oaks in the West grow on privately owned land, making it imperative to broadly share information that may help preserve and restore these valued ecosystems.

Oak species along the West Coast are facing a number of threats, ranging from disease and insects to development and competition for space from other trees.

Each threat alone is taking its toll, say Forest Service scientists. That they're all happening at once is alarming. It may mean that the oak communities that now grace the valleys and coastal lowlands of the Pacific Northwest and the dry hillsides of central and coastal California are approaching a tipping point.

"In the Pacific Northwest, we've lost about 95 percent of the oak and prairie habitat that existed in the early to mid 1800s," says Connie Harrington, a research forester with the Pacific Northwest (PNW) Research Station in Olympia, Washington. "Oak communities here are far more endangered than old-growth conifer forests because they were less common to begin with."

In the Pacific Northwest where conifers dominate the landscape, oak woodlands, savannas, and prairies represent unique habitat for many wildlife species. The trees provide homes for birds, mammals, reptiles, amphibians, invertebrates, and many plant species, some of them endangered or threatened. Acorns provide food for mammals and birds

Key Findings

Oregon white oak release

- Removing all Douglas-fir trees growing near an Oregon white oak is more effective than removing just a few.
- Release operations are best done in the fall, winter, or early spring when the oak tree is dormant.

Oregon white oak planting

- Seedlings with fibrous root systems will grow better after planting than those with just a few woody roots. Fibrous roots can be encouraged by “air-pruning” container-grown seedlings.
- Seedlings do best in a weed-free environment with adequate water and protection from deer and rodents.
- Growth of planted seedlings may be slow during the first few years because the plant is investing in new roots.

Sudden oak death (*Phytophthora ramorum*)

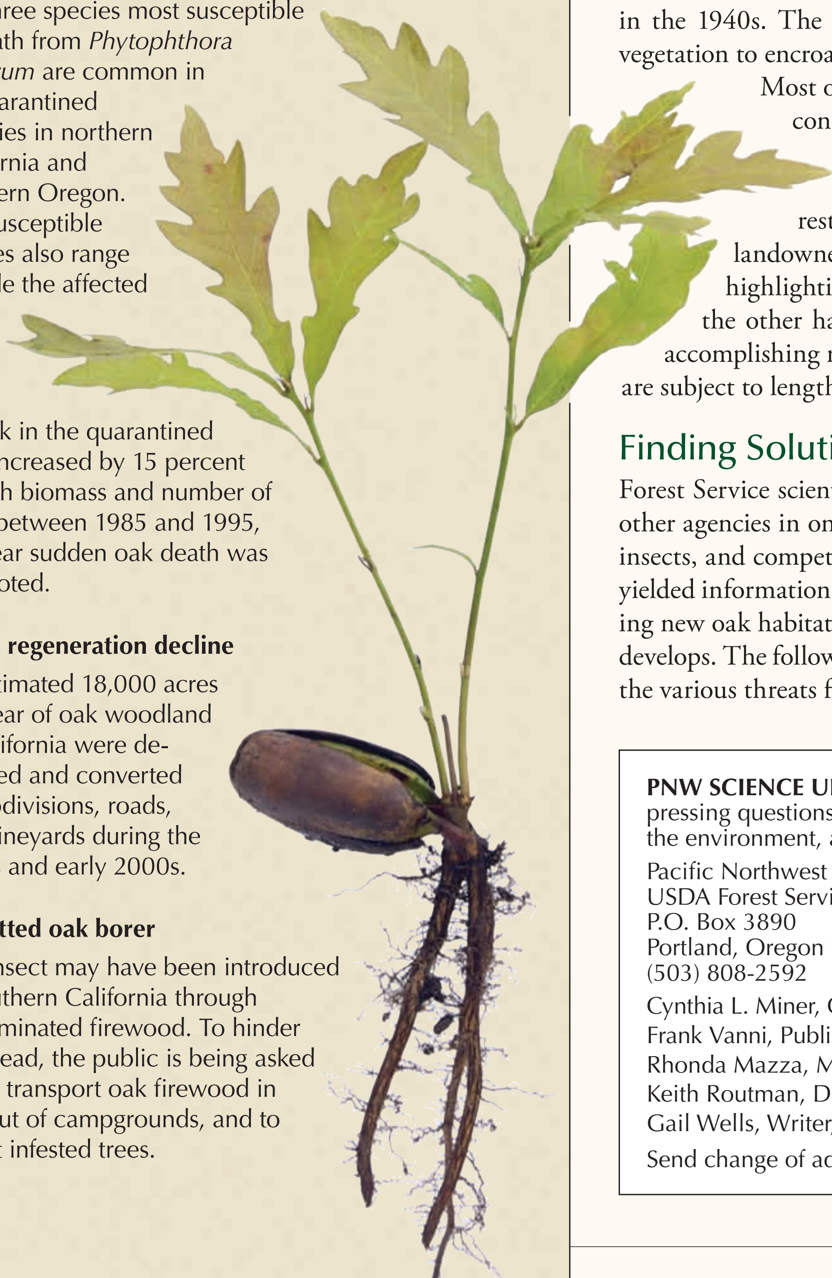
- The three species most susceptible to death from *Phytophthora ramorum* are common in 14 quarantined counties in northern California and southern Oregon. The susceptible species also range outside the affected area.
- Tanoak in the quarantined area increased by 15 percent in both biomass and number of trees between 1985 and 1995, the year sudden oak death was first noted.

Blue oak regeneration decline

- An estimated 18,000 acres per year of oak woodland in California were de-forested and converted to subdivisions, roads, and vineyards during the 1990s and early 2000s.

Goldspotted oak borer

- This insect may have been introduced to southern California through contaminated firewood. To hinder its spread, the public is being asked to not transport oak firewood in and out of campgrounds, and to report infested trees.



and, in turn, wildlife often function as tree planters. On Vancouver Island in British Columbia, for example, uneaten acorns cached by Stellar’s jays are the primary way oaks become established on new ground.

Ten Millennia of Management

Historically, oak communities along the west coast owe their existence to land management; namely, 10,000 years or more of seasonal burning of prairies by Native Americans. The frequent, relatively cool fires spared the fire-resistant oaks and renewed the grasses of the prairies, which sustained the deer and other game needed for food. The fires killed encroaching brush and trees, leaving oaks with plenty of sunlight. The fires also killed insects that ate or damaged the acorns sought by Native Americans. Fire management changed with the arrival of Euro-American settlers in the 1840s. Early settlers in Washington curtailed the annual burning, whereas in California and southern Oregon, it continued to some extent but slowed after the Smokey Bear fire-prevention campaign was initiated in the 1940s. The exclusion of fire has allowed Douglas-fir and other vegetation to encroach and compete with the oaks.

Most of the oak land in the West is privately owned today, a consequence of Euro-American settlement patterns. This ownership pattern has implications for management and restoration of oak woodlands. On one hand, restoration requires cooperative efforts by many private landowners rather than just a few federal and state agencies, highlighting the importance of widely sharing information. On the other hand, private land managers may have an easier time accomplishing restoration projects than federal agencies, whose plans are subject to lengthy review processes.

Finding Solutions

Forest Service scientists are working with cooperators at universities and other agencies in ongoing efforts to counter the threats posed by disease, insects, and competition for space. In some cases, the science has already yielded information useful to landowners interested in preserving or creating new oak habitat. Other recommendations will surface as the research develops. The following articles highlight some of this research addressing the various threats facing oaks along the west coast.

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U.S. Forest Service

Tanoaks killed by sudden oak death along Bolinas Ridge, Marin County, California.

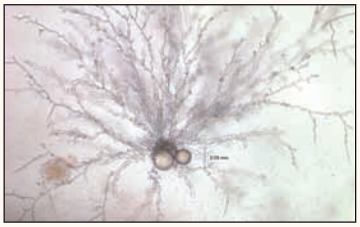
A Closer Look

OAK ECOSYSTEMS along the west coast face a variety of threats. These threats differ by oak species and locale, but the consequences are similar: as oaks disappear, wildlife habitat and ecological diversity not found in other forest types is lost. Ongoing research is yielding information that can be used to develop conservation strategies.

The Threat: Sudden Oak Death

In 1995, hikers noticed dead tanoak (*Lithocarpus densiflorus*) along trails on Mount Tamalpais in Marin County, California. By 1999, landowners in the county began noticing coast live oaks suddenly dying. Upon closer inspection, observers noticed black or reddish-brown sap oozing from tiny holes in the bark of the infected trees. Within months the trees were dead. Baffling and alarming, the disease was dubbed "sudden oak death."

In 2000, a plant pathologist tracked down the associated pathogen. It belonged to a genus of water molds called *Phytophthora*, whose species attack many plants and kill several economically important ones. True to their name (which means "plant destroyer"), *Phytophthoras* have long been known to cause devastating plant diseases; the Irish potato famine in the mid-1800s was triggered by a *Phytophthora* infection.



Jennifer Parke

The sudden oak death pathogen, Phytophthora ramorum*, in culture.*

Once identified, *Phytophthora ramorum* was found in plant nurseries in 22 states and also in Europe. *Phytophthora ramorum* doesn't kill most of its hosts; instead, plants such as rhododendron and camellia become carriers for the highly contagious pathogen. The nurseries have undertaken intensive sanitation procedures to control and eradicate it. In the wildlands, the pathogen has killed millions of tanoaks, coastal live oaks (*Quercus agrifolia*), and some black oaks (*Quercus kelloggii*) along the central coast of California and in southwestern Oregon.

California bay laurel (*Umbellularia californica*) and tanoak are apparently excellent hosts for the pathogen, enabling it to produce lots of spores, explains Tara Barrett, a research forester with the PNW Research Station who studies California oaks. A damp, rainy climate also seems to facilitate its spread. Bay laurel (also known as Oregon myrtlewood) and tanoak are common throughout the infested area, allowing for easy transmission and spread. "For these reasons," Barrett says, "The disease is very likely to continue to spread through coastal California and Oregon forests."

Phytophthora ramorum spores are spread by wind-driven rain, land on susceptible host trees or plants, grow into host tissue, and begin to reproduce. Eventually they make their way into the tree's xylem, impairing its ability to transport water. Within a few years, or perhaps as soon as the following summer, the tree becomes water stressed and dies.

Stopping the spread of infected plant tissue is particularly important, and has led to the quarantine of 14 counties in California and a smaller area in southwest Oregon. Spores can also be spread in running water and on muddy boots, livestock hooves, and car tires.

Tara Barrett

A leaf sample of California bay laurel infected by Phytophthora ramorum*, the pathogen that causes sudden oak death.*

Since its discovery, the disease has not spread much beyond the coastal California counties and the small area in southwestern Oregon where it was found. Scientists speculate that this may be a result of drier weather condition in recent years.

Research response

The *P. ramorum* pathogen is "amazingly versatile," says Susan Frankel, who directs the sudden oak death research program at the Forest Service's Pacific Southwest Research Station. It combines a broad host range with a wide variety of attack strategies, and thus it still holds many mysteries for scientists. Why does it kill some of its victims and only sicken others? What sort of genetic resistance, if any, is there in host species that aren't killed by the disease? In how many ways is the disease transmitted, and what are the vectors? Do environmental factors influence a plant's susceptibility? If sudden oak death were allowed to spread unchecked, how far would it go?

Recent molecular research is beginning to uncover some of *P. ramorum*'s secrets. Scientists have now sequenced its genome and those of two other *Phytophthora* species. They have found that these pathogens have a large arsenal of proteins, such as toxins, protein inhibitors, and enzymes, that enable them to overcome a host plant's immune system and then invade and sicken or kill the plant. The *Phytophthora* genome is also relatively large, and its genes seem to adapt quickly in the face of challenges from hosts' defense systems.

Scientists sequenced the genome of the pathogen that causes sudden oak death and found that it is well equipped to overcome a host plant's immune system.

It also helps scientists to know what the affected forests looked like before sudden oak death was detected. Barrett and her colleague Karen Waddell, also a research forester with the PNW Research Station, analyzed three Forest Service inventories of early-1990s forest conditions within the quarantined California counties.

These inventories constitute a database of spatial information about the forests as they were before the disease made its appearance. Data include the species and distribution of trees that were present, which species were dominant, which size and age classes were represented, mortality rates for the different species, and ownership (public or private).

Barrett and Waddell's analysis revealed that, collectively, the three most susceptible oak species were widespread throughout the quarantined area and dominated about 36 percent of the forest. Curiously, Barrett and Waddell also found that numbers of tanoak trees in the quarantined area had increased by more than 15 percent in the decade before the disease was discovered. This increase may stem from forest management in the mid 1900s that selectively harvested more valuable conifers, allowing ingrowth by tanoak. Fire suppression may also have played a role. "It's very interesting," says Barrett. "The high level of tanoak has probably helped spread the disease, and the high level may also be an aberration in the natural range of variation for coastal forests."

"It's pretty definite that we'll see major changes in coastal forests," Barrett continues. "It's uncertain whether the disease could expand to places like the Sierra Nevada, however, even though many of the host species are there too. That it hasn't shown up yet is a very good sign." Various risk maps and models to project the spread of the disease have been developed. Barrett's and Waddell's work provides a reference baseline for future monitoring of the pathogen and its impacts.

Climate change is expected to intensify the effects of *P. ramorum* on coastal forests. Two major waves of sudden oak death have occurred in Oregon and California: the first between 1998 and 2001 and the second between 2005 and 2008. These were years of warm, wet springs followed by hot, dry summers—a pattern consistent with climate-change scenarios predicted for the Pacific coast. "There are many unknowns," says Frankel, "but in general, those are the conditions under which we expect the pathogen to spread and kill trees."

The relationships among pathogens, hosts, and weather are complex and highly variable, but most researchers agree that changes in temperature and moisture regimes will probably have significant and mostly destabilizing effects on forest ecosystems. Warmer weather will likely increase the rate at which pathogens evolve around their hosts' immune defenses. And, because an unstable climate makes year-to-year comparisons problematic, it will be harder to predict the timing and magnitude of disease outbreaks.

Rhonda Mazza

If left undisturbed, encroaching conifers will eventually shade out the oaks.

The Threat: Invasion by Douglas-Fir

The range of Oregon white oak (*Quercus garryana*) extends from southern British Columbia to southern California. It is most common in the lowlands west of the Cascade Range. It is valued not so much for its products (although it is sometimes used for firewood, wine barrels, cabinets, flooring, and axe handles, among other things) as for its contributions to natural and human ecology. The stately oaks have enduring aesthetic appeal and provide essential habitat for wildlife such as Lewis's woodpecker (*Melanerpes lewis*), acorn woodpecker (*M. formicivorus*), and western gray squirrel (*Sciurus griseus*), and for rare plants such as Kincaid's lupine (*Lupinus sulphureus kincaidii*), an essential part of the habitat for the endangered Fender's blue butterfly (*Icaricia icarioides fenderi*).

Oregon white oak can live in a wide range of conditions, from the cool, humid coastal climate to hot, dry inland environments. It grows best on moist, fertile sites, but it can exist in very dry conditions as well.

The one thing it can't tolerate is shade. Seasonal burning kept the other, less-fire-tolerant species at bay. When settlers decreased the burning in the 1850s, the lengthened intervals between fires facilitated invasion by Douglas-fir (*Pseudotsuga menziesii*), bigleaf maple (*Acer macrophyllum*), and other trees and shrubs. Douglas-firs grow more quickly than oaks and will eventually overtop them. The shaded oaks may persist for a few decades, but will eventually die.

Many plant and wildlife species are found only in oak-prairie systems. If we lose the system, we lose the species.

Research response

Scientists, landowners, and conservationists are alarmed about the dwindling of the Northwest's oak lands and the cultural and ecological legacy they represent. "It's important to preserve as much as possible of the region's biodiversity," says Connie Harrington, leader of the PNW Oak Studies Group. "Many plant and wildlife species in oak-prairie systems aren't found anywhere else in the Northwest. If we lose the system, we lose the species."

The group has studied Oregon white oak across its range and identified ways to restore oak communities on sites where the oaks have been overtopped by other trees and to get them established on new sites. The researchers found that oak regeneration is not the problem, but rather it is competition from Douglas-fir. Oak stands also contain other native hardwood competitors such as bigleaf maple and sweet cherry (*Prunus avium*), as well as exotic species such as Scotch broom (*Cytisus scoparius*).

To determine the most effective way to release Oregon white oak from overtopping conifers ("release" means to remove some or all of the competing vegetation to restore light, water, and nutrients to the oaks), Harrington and her colleague Warren Devine teamed with foresters at Joint Base Lewis-McChord, a military reservation near Tacoma, Washington. They used the base's oak woodlands to test three levels of release: full release where all the Douglas-fir from within one tree-height were

Connie Harrington

A volunteer and a technician sort oak roots by size categories.

Connie Harrington

A field crew plants acorns as part of a study that led to guidelines for reestablishing native oaks in Washington and Oregon.

removed; half-release where all the Douglas-fir from within half a tree height were removed; and a control where only a few Douglas-fir were removed.

The oaks responded best to full release. There was no evidence that a gradual release to avoid "shocking" the oak was necessary. Within 5 years the oaks had better stem growth, more new branches, and bigger crowns, and they produced more acorns. The researchers also found that generally Douglas-fir could be removed without unduly damaging the oaks. In situations where this wasn't possible, for example when the conifer had grown up through the oak's crown, girdling the trunk of the Douglas-fir was an effective way to release the oak without damaging it.

Harrington and Devine distilled their findings in a set of practices for landowners. Their manual, *A Practical Guide to Oak Release*, explains how to determine which oak stands most need to be released and in what order to treat them, how to design the release to gain the maximum benefit to the oaks while meeting other management objectives, and what growth improvements to expect after the oaks are released.

They have also published a book, *Planting Native Oak in the Pacific Northwest*, that guides the landowner through the essential steps of planting and cultivating young oak stands. Of note, they determined that root structure, or morphology, plays a determining role in a seedling's ability to thrive once transplanted. A seedling with a fibrous root system is better off than one with a single woody taproot. Desirable root formation can be encouraged by various mechanisms. A technique called air pruning, which uses bottomless pots raised above greenhouse tables, encourages more fibrous roots to develop rather than a single woody taproot that circles the bottom of the pot. For seedlings grown in a nursery bed, undercutting (pulling a special sharp blade through the soil) and wrenching (shaking the seedling by running a vibrating blade through the soil to reduce soil-root contact) encourage fibrous root systems.

Another aspect of the research evaluated whether Oregon white oaks are producing enough acorns to sustain their communities. Dave Peter, a plant ecologist with the PNW Research Station, joined by other researchers and many volunteers, surveyed oak trees for acorn production on sites ranging from Whidbey Island, Washington, to Roseburg, Oregon. The trees ranged in age from 11 to over 300 years.

They found that trees generally start producing acorns at around age 20 and increase production until age 80 or so. Trees with tall narrow crowns—typical of oaks growing in dense competition—produced fewer acorns than those with broad, full crowns typical of more open-grown trees. The most productive trees were growing in well-drained, loamy soils or in parks where they were being watered and

Citizen Scientists

If scientists want to study the fine points of acorn production in Oregon white oaks, somebody has to go out year after year and count a lot of acorns on a lot of oak trees. Dave Peter and Connie Harrington do this kind of legwork as a matter of course, but they can't do it all. The season for observing acorns is short. The acorns need to have turned yellow or brown so they are visible against the green leaves, but once ripe, they fall quickly and are eaten by many species. So, for annual acorn surveys, the scientists rely heavily on the time, energy, and passion of more than 70 volunteers.

Some of the acorn counters are landowners, some work for land management agencies or conservation organizations, and some are just interested lay people. "It's citizen science," says Harrington. "Without our volunteers' help it would be impossible to gather data throughout the range of Oregon white oak during such a short time span."

The volunteers don't actually count each acorn. Rather, they estimate the level of production on a one-to-four scale. The same people usually return to the same trees each year, which enhances the consistency of the estimates over time. Another group of volunteers plants oak seedlings, recording planting methods and site characteristics and then going back yearly to measure the seedlings' growth.

Citizen scientists sometimes contribute to important and surprising discoveries. Volunteers with the Midpeninsula Regional Open Space District, in the San Francisco Bay area, discovered that tanoak trees are pollinated not just by wind, like true oak species, but also by insects. Nine volunteers from the district observed flowering tanoak trees during July and August of 2009. They watched each tree for 10 minutes and noted all the bees, flies, beetles, ants, and other insects that visited the flowers.


Connie Harrington

A researcher surveys acorn production on an Oregon white oak.

The volunteers were helping University of California plant pathologists Matteo Garbelotto and Katy Hayden and Forest Service geneticist Jessica Wright in an ongoing investigation into whether some tanoaks might be genetically resistant to *P. ramorum*. Because tanoaks currently have little commercial value, their basic biology has not been widely studied. The scientists didn't know insects had a role in spreading their pollen. Knowing tanoak's pollination habits is important because it will help scientists understand how genes for resistance are transmitted from one generation of trees to the next.

fertilized. (Soils in the Northwest tend to drain very quickly, in contrast to many soil types in California where watering oaks is not encouraged.) Trees on more marginal sites were less productive. "Many of these factors can be altered by management activities," says Harrington. "Understanding the factors that influence production of acorns could help managers increase the size of their acorn crop."

This growing attention to the fate of Oregon white oak comes at a critical time. The oaks that are fighting for their lives under a canopy of conifers have very little time left—a few years, maybe a few decades. "It's a short window," Harrington says. "If those trees are going to be released and survive, time is of the essence."


Connie Harrington

Sprouting Oregon white oak acorns.

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Between the early 1990s and 2000s, about 18,000 acres of hardwood forests per year were lost to other uses in California.

Research response

Blue oak woodland is the most common deciduous forest type in California and has been heavily influenced by human settlement and development. Waddell and Barrett's recent analysis of forest inventory data on blue oak woodlands paints an unsettling picture of another forest community that may be headed for profound change. It's too early to reach for answers, the researchers say, but documenting the decline is the first step toward a better understanding of the interplay of contributing factors.

Blue oak decline is part of a larger dynamic of deforestation-by-conversion in California's hardwood forests. Between the 1930s and the 1970s, when land was being cleared for ranching, roughly 65,000 acres of hardwoods were lost annually. This slowed to about 6,000 acres per year between the early 1980s and 1990s, according to Barrett and Waddell. However, between the early 1990s and early 2000s, the rate had risen to 18,000 acres per year, or about 2 percent per decade, with much of the converted woodland ending up as subdivisions or vineyards. "It's not a huge rate of loss," says Barrett, "but it's of concern, because it's been going on for a long time."

Why the rate of decline slowed after 1970 is one of many potential research questions, Barrett says. Was it due to a flagging ranch economy, such that people stopped clearing land for range and pasture? Or did a land-use education and incentive program created in the mid-1980s cause landowners to step up their conservation efforts? What effect can be expected from land-use regulations, such as the 2002 rule requiring counties to develop management plans for privately owned oak woodlands? These and other questions represent a field ripe for research.

As in Oregon, the prospect of losing these woodlands has inspired California landowners and concerned citizens to get involved in oak conservation. "The loss of oaks has a social impact disproportionate to the area they occupy," says Barrett. "Many oak woodlands are in the high-visibility areas where people live, work, and play, and people love their oaks."

The Threat: Deforestation, Inadequate Regeneration

Blue oak (*Quercus douglasii*) woodlands cover about 3 million acres in California, mostly along the Central Valley. Around the beginning of the 20th century, observers began to note that these woodlands were not regenerating as fast as they used to. "People have been commenting on this for a long time," says Barrett. "They noticed that there weren't enough little trees to replace the big ones, and that there were large portions of the landscape with very few seedlings and saplings."

Measurements taken by Forest Service scientists nearly 100 years after those first observations have confirmed and quantified them. Blue oak is indeed suffering from a lack of regeneration, which may be leading to a long, slow population decline. "Although we don't have historical data from before Euro-American settlement, the indirect data are very strong: given the number of blue oaks today, population recruitment must have been higher in the past," explains Barrett. Results from studies by the Integrated Hardwood and Range Management Program at the University of California, Berkeley, and others point to several possible causes, including drought, browsing by wildlife and cattle, and competition from other plants.

> Concern over the loss of blue oak woodlands led to conservation-driven regulations as well as an education and incentive program for private landowners.

The Threat: Goldspotted Oak Borer

An insect that may have ridden in on firewood has killed thousands of mature oaks on federal, state, private, and tribal lands in southern California. Since 2002, managers on the Cleveland National Forest in San Diego County have been concerned about the widespread decline and death of oak trees in certain areas. The forest was surveyed for insects and diseases, but nothing was found that could explain the magnitude of the loss. The oaks' decline was blamed on southern California's 6-year drought.

In May of 2008, suspecting that something more than drought was at work, Tom Coleman, an entomologist with the Pacific Southwest (PSW) Research Station, and four colleagues surveyed dying oaks on the Cleveland National Forest again. They found that mature coast live oak and California black oak trees on the Descanso Ranger District were under attack from a new insect pest.

Coleman linked the continuing oak mortality to the goldspotted oak borer (*Agrilus coxalis*). The insect had been documented for the first time in California in a 2004 survey, but at the time, was associated with the ongoing oak loss. The goldspotted oak borer has been present in southeastern Arizona, Mexico, and Guatemala since the 1800s, but it has never been linked to oak damage or death in those areas. Anecdotal evidence suggested that it may have arrived on firewood brought in from either Arizona or Mexico.

Oak mortality from the goldspotted oak borer continues to rise as the zone of infestation expands across all land ownerships. Transporting infested firewood may spread this problem into additional areas of the state.

Research response

Prior to 2008, nothing was known about the biology and life history of this once rarely collected insect. Coleman and his colleagues immediately began studying its life history. They've since observed that the larvae of the goldspotted oak borer burrow under the bark of the trunk and larger limbs of the bigger trees, feeding on the phloem and cambium. The tissue dies in patches and strips, eventually girdling the tree. Dormant larvae in the outer bark attract woodpeckers, which tear away the bark to reveal the brick-red phloem. Stains resulting from extensive larval feeding appear as darkened spots and a red-and-black blistering of the bark exterior. Tiny D-shaped exit holes in the bark are another symptom. A tree infested with goldspotted oak borer larvae prematurely drops its leaves, and the remaining foliage fades to a dull gray. Within a few years the tree is dead.

The goldspotted oak borer may have migrated to California in larval or pupal form on firewood, but it is also possible, says Coleman, that the insect's range is expanding—no one yet knows for sure. The only confirmed hosts so far are coast live oak, canyon live oak, and California black oak, but other species may prove susceptible. Moreover, the wide range of the main hosts suggests that the insects have a high potential to spread farther north.


Tom Coleman

The goldspotted oak borer is a new insect threat to oaks in California. Adults are about 2 inches long and are rarely seen.


Mike Lewis

Wood damage caused by the goldspotted oak borer.


Mike Lewis

The goldspotted oak borer may hitch rides on firewood cut from infested trees.

The goldspotted oak borer is related to the emerald ash borer and seems to have a similar life history and devastating effects on hardwood trees. For now, managers are urged to follow guidelines for controlling the better-known species within the genus. Strategies include treating high-value trees with insecticides, removing and burning infested wood, covering wood with plastic tarps (on the theory that trapping the sun's heat may kill larvae and pupae), chipping wood into small pieces, and avoiding the transportation of firewood.

Moving Forward

Researchers, land managers, the public, and policymakers all have roles to play in the preservation and restoration of oak lands. Upon identification of a disease or insect threat, containment and quarantines are the initial defense. As research yields new information about the life history of these threats, management guidelines can be fine tuned to better target the threat. Threats to oak ecosystems stemming from land-use decisions emphasize the importance of sharing information and educating landowners about steps they can take to sustain oak habitats. Because most oak lands along the west coast are on private land, saving these valued ecosystems will take the efforts of many.

Dave Azuma

Looking for Remedies for Sudden Oak Death

THE WATER MOLD that causes sudden oak death thrives in cool, moist environments such as coastal forests and nursery shadehouses. Like other *Phytophthoras*, it produces several kinds of spores. Some thick-walled spores may help the organism survive through periods of drought. Other spores are like little sacs and release tailed zoospores when immersed in cool water. Once they land on the wet surface of a susceptible plant, the zoospores spread through a film of water until they find a place to settle. Then they lose their tails and become cysts that puncture the cell walls of the host organism. They grow long strands that push into the plant's tissues, killing cells as they go.

The spores are carried by wind and water; they can also travel in the mud on tires and hikers' boots. They attack the bark of susceptible trees and leaves and stems of other host plants. Trees with sudden oak death may live for more than 2 years after the onset of infection, but frequently the weakened trees are colonized by other fungi or beetles, which may hasten their death.

The Forest Service is funding several research projects aimed at halting the spread of sudden oak death. These projects range from developing fungicides to looking for genetic resistance that appears to exist in some trees within a species. Given that sudden oak death kills a number of species and uses even more as hosts, a multipronged attack against it makes sense.

Cedar heartwood has long been known to resist decay and have natural antimicrobial properties. Scientists began testing to see if something in cedar heartwood would inhibit *P. ramorum*.

In the California Bay Area, researchers are examining the possibility that some tanoaks may be genetically resistant to *P. ramorum*. Acorns from these trees have been planted and the seedlings are being monitored. It will likely take years before this study yields definitive answers, but if genetic resistance is identified, acorns from these trees could be used to replant areas where tanoak has been wiped out. Another project in California is testing the efficacy of a phosphate-based fungicide on tanoak and California bay laurel.

In Oregon, Rick Kelsey, a research forester with the PNW Research Station, is experimenting with natural fungicidal compounds that may limit the spread of *P. ramorum*. He and colleagues Dan Manter, of the USDA Agricultural Research Service, and Joe Karchesy, of Oregon State University, have shown that extracts from the heartwood of certain aromatic conifers will kill *P. ramorum* spores in a petri dish. "Cedar heartwood has long been known to resist decay and have natural antimicrobial properties. For us, it was a logical progression to see if there might be something in cedar heartwood that would inhibit *P. ramorum*," says Kelsey. Their work is part of a larger effort to understand, at a chemical level, the interactions between *P. ramorum* and its host.

Field tests found less P. ramorum *in the soil under western redcedar chips in this grove of California bay laurel.*

In one experiment, researchers placed chips from the heartwood of Alaska yellow-cedar (*Callitropsis nootkatensis;* previously *Chamaecyparis nootkatensis*) into a dish with spores of *P. ramorum*. "Under a microscope you could see the spore membranes disintegrate and burst," says Kelsey.

The team went on to test heartwood extracts from three species of cedar and from other trees. They found that extracts from the heartwood of incense-cedar (*Calocedrus decurrens*) and western redcedar (*Thuja plicata*) were most effective at killing *P. ramorum* spores. Yellow-cedar and Port-Orford-cedar (*Chamaecyparis lawsoniana*) were moderately effective, whereas redwood extract was ineffective.

This made Kelsey and his colleagues wonder whether the actual chips, placed out in the woods, might have a similar antimicrobial activity. "We speculated that if the chips were laid down and got leached with rainwater, it might impact the spores," Kelsey says.

To test this hypothesis, they sewed chips from redcedar and redwood into nylon mesh bags and laid them under a grove of infected California bay laurel trees in a park near Novato, California. Tests of the soil and litter layer conducted from late winter through summer showed significantly less *P. ramorum* DNA in the litter under the redcedar chips than under the redwood chips. These results were consistent with laboratory trials.

The findings are very preliminary, says Kelsey, but they suggest that spreading a mulch of redcedar or yellow-cedar chips over a trail through a sudden oak death–affected area might keep spores from hitchhiking out on people's boots or bicycle tires.

Kelsey and his colleagues have identified individual compounds in cedar heartwood that are effective against the spores, which potentially could be used to develop commercial products to combat the pathogen. The researchers are also investigating to what extent other compounds in host plants contribute toward their resistance to the disease.

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Science Update

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SUMMARY

Oaks in the Pacific West are facing four serious challenges that may trigger major changes in oak ecosystems. In Washington, Oregon, and northern California, fire exclusion has enabled Douglas-fir to encroach on the sun-loving Oregon white oak. In California, sudden oak death is taking a toll on tanoaks, black oaks, and coast live oaks, and in central California, blue oak and valley oak are not regenerating fast enough to replace older trees. The goldspotted oak borer, first detected in 2004, is playing a major role in oak mortality in southern California. All along the west coast, conversion of oak woodlands and savannas to agricultural and residential uses has dramatically reduced oak coverage since settlement by Euro-Americans.

Scientists with the Pacific Northwest and Pacific Southwest Research Stations are studying these various threats and developing practical strategies for addressing them. Most oak woodlands along the west coast are privately owned, making it imperative to broadly share information that may help preserve and restore these valued ecosystems.

For More Information (*from page 11*)

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