

Recent Increases in Blue Oak Mortality

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Elevated levels of blue oak mortality have been reported in various parts of California over the past few years. Reported oak mortality tends to occur in a scattered or patchy pattern across the landscape. In some places, other species, such as valley oak have been affected. Concerned landowners have wondered whether another introduced pest or pathogen could be the source of this elevated mortality. In coastal California counties from Monterey County north, sudden oak death, caused by the introduced water mold *Phytophthora ramorum*, has killed many thousands of coast live oak, canyon live oak, California black oak, Shreve oak, and tanoak trees. More recently, several other new invasive species have also been found attacking California oaks. These include gold spotted oak borer, two invasive shothole borers that have become established in parts of Southern California, and more recently, an exotic ambrosia beetle (*Xyleborus monographus*) that was initially found near Calistoga in Napa County.

Fortunately, evidence to date does not suggest that the various scattered areas of blue oak mortality are due to a specific invasive pest. Rather, much of this mortality is related to the severe drought that California experienced from 2012 through 2016. This drought was the most severe since weather data has been recorded in California, and well beyond that, based on tree ring studies.

Drought-related effects

Drought-related oak mortality mostly began to surface after several years of drought and was more likely to appear first in areas with chronically low rainfall and high evaporative demand. California's warming climate has led to longer, hotter dry periods that can severely stress even drought-adapted species like blue oak. A recent study of blue oak woodlands in the lower elevations of Sequoia National Park used recent and older data to document that standing blue oak mortality rates increased dramatically during the 2012-2016 drought, from around 5% in pre-drought data sets to 23% by 2017 (Das et al 2019. Tree mortality in blue oak woodland during extreme drought in Sequoia National Park, California. *Madroño* 66(4): 164–175).

Although severe drought alone may be able to kill oaks, quite often tree mortality involves other pests and pathogens that target trees under stress. These include an assortment of opportunistic wood boring beetles and decay fungi, especially certain sapwood decay fungi. For example, in some areas widespread valley oak mortality has occurred where groundwater levels have dropped rapidly, such as in areas where a relatively shallow water

table has been lowered due to rerouting of watercourses or dewatering related to sand mining. Excessive use of shallow groundwater during drought can impose the same type of induced drought stress. If the drop in the water table happens quickly enough, mature valley oaks may not adapt fast enough and may become severely drought stressed. As these trees become severely stressed, commonly over several years, opportunistic pests and pathogens degrade the sapwood, hastening tree death. If lowering of the water table is slower or reversed after a short time, trees may be able to adapt by deeper root growth or may recover to some degree if stress has not been too severe.

In contrast to valley oak, which mainly occurs where soils are deep and groundwater is typically available through most or all of the dry season, blue oaks are adapted to much drier sites. Based on a study completed in 1993 (Swiecki and Bernhardt 1993. Factors affecting blue oak sapling recruitment and regeneration, <http://phytosphere.com/publications/Blueoakregeneration.htm>), we concluded that blue oaks tend to occur in the best areas of the worst sites or in the worst areas of the best sites. Blue oaks can do quite well in good soil in moist sites, but under these conditions, they tend to be out-competed by faster-growing trees (e.g., valley oak, coast live oak, California bay). In our yard, comparing trees grown from acorns planted several decades ago (on clay loam soils with a shallow water table), the valley oaks are many times the size of the blue oaks. Due to competition from faster growing, taller trees, in sites with good growing conditions, blue oak is most competitive in poorer areas where the soil water supply is more limited.

Because blue oaks can tolerate much drier conditions than most other native trees in its range, they become dominant in areas with low rainfall and poorer soils, where they are often mixed with the drought-tolerant foothill pine. Although blue oaks are adapted to tolerate drought conditions, they are not desert plants. During severe drought, conditions at normally dry sites can become extreme, and dip below the threshold of blue oak site tolerance. These are the types of sites where much of the recent blue oak mortality has been observed. These intrinsically dry sites (low precipitation, shallow/rocky soils with low water-holding capacity, on hot south-facing slopes) have had the worst of it during the drought. Between 2012 and 2016, California experienced the worst drought in 500+ (some say, 1,200) years. Under these extreme conditions, the “best areas of the worst sites” were no longer all that good, and in some cases resulted in water stress that overtaxed blue oaks’ prodigious drought tolerance.

Due to long-term consequences of stresses and associated pest/disease interactions, elevated levels of oak mortality can continue for many years after the end of the drought. A drought-stressed tree may die during the drought, one- or two-years post-drought, or even several to many years later. The adage that oaks live for a hundred years and die for a hundred years is based on the idea that few things can kill an oak quickly, but an

accumulation of insults over time can eventually do it in. Processes that are set in motion during the drought can play out over several to many years.

Historically, most oak mortality in California blue oak woodlands has been caused by various decay fungi, including canker rots and some root-rotting decay fungi. The effects of these agents can be accelerated by severe stress, such as that imposed by severe drought. The destruction of heartwood and sapwood caused by decay fungi is not reversible when conditions improve. Because the pathogens can respond to the moister conditions quicker than the trees, severe drought followed by heavy precipitation can accelerate decline due to agents such as root rots.

Soil types, hydrology, and rainfall amounts vary widely throughout the state and can vary over a short distance within a single watershed. On a given soil type, trees on south-facing slopes will experience more water stress than those on north-facing slopes due to differences in solar radiation. When assessing whether excess mortality may be associated with drought, consider where it occurs across the landscape. Is it more prominent on south-facing slopes or in areas of thin soils? Does the timing of mortality correspond with the drought and expected post-drought effects?

Pests and pathogens

It is important to note that drought is not the only factor that is responsible for mortality of blue oak or other oaks. Unusual mortality could be related to native or introduced pests and pathogens, and may not be due to a single cause. For example, even within areas generally affected by sudden oak death, many oaks and tanoaks are killed by other agents.

With the combination of climate change and introduced pests and diseases, we can expect more deviations from what was considered normal, including changes in the ranges of both native and exotic agents that attack oaks. Most new invasive pests and pathogens are introduced by human activities. For most wood boring beetles, movement of infested firewood and other raw wood is a major means of introduction. For root-rotting *Phytophthora* species and some insects, movement of nursery stock is a primary means of introduction, including past plantings of stock used for restoration. Soil movement, including movement from contaminated areas to other areas on vehicles, equipment, livestock, and shoes, can also be a route for spread of *Phytophthora* and other soilborne agents. Consequently, new introductions of exotic pests and pathogens are more likely to occur first near homesites and other developed areas, along roads, maintained utility corridors, and near heavily used points of entry into a property rather than in remote areas with little or no human activity.

Some introduced pests and pathogens produce unusual symptoms, such as the extensive bleeding associated with the gold spotted oak borer and invasive shothole borers. However,

some introduced pests and pathogens cause symptoms that resemble drought effects. In Santa Clara County and elsewhere, we have documented sites where native blue oak and other oak stands showed tree decline and death associated with introduced root-rotting *Phytophthora* species. Because these pathogens destroy fine feeder roots, they can induce water stress in the presence of adequate soil moisture. Phytophthora root rots can also exacerbate the effects of drought because they reduce the total root volume that trees use to absorb soil moisture.

Diagnosing the causes of tree mortality is not a simple process and may require the involvement of specialists. Forest health and resource specialists from UC Cooperative Extension and CalFire can help landowners assess oak tree mortality to determine possible causes. However, determining the cause of oak mortality can be a daunting task even for experts, and may be impossible if trees have been dead for a long time. Because tree decline and death often involves several interacting factors, it is very helpful if the landowner can provide detailed information about site history and the onset of symptoms. Good digital photos, showing both relevant close-ups and wide-angle views of the affected locations can provide a way to easily record and store your observations and share them with specialists.
