



Forest Service
U.S. DEPARTMENT OF AGRICULTURE

2021 Aerial Detection Survey Results: California



State & Private Forestry, Region 5
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COVER PHOTO

Ongoing severe ponderosa pine mortality within the Sequoia National Forest, west of the John Krebs Wilderness area. Smoky conditions were due to many large wildfires in the region.

Photo by: Nicholas Stevens, USFS

Prepared by Jeffrey Moore, Nicholas Stevens, and Meghan Woods

USDA Forest Service, Region 5

Contributors

Aerial Surveyors:

Jeffrey Moore, USFS

Stephen McKelvey, Quercus Consultants, Inc.

Nicholas Stevens, USFS

GIS Support:

Karen Endres, USFS

Micha Salomon, USFS

Scan and Sketch Support:

Ashley Hawkins, USFS

Chris Lee, CALFIRE

Cynthia Snyder, USFS

Contributing Editors:

Kayanna Warren, USFS

Sheri Smith, USFS

Special Thanks to the Pilots:

Paul Clark

Steven Datema

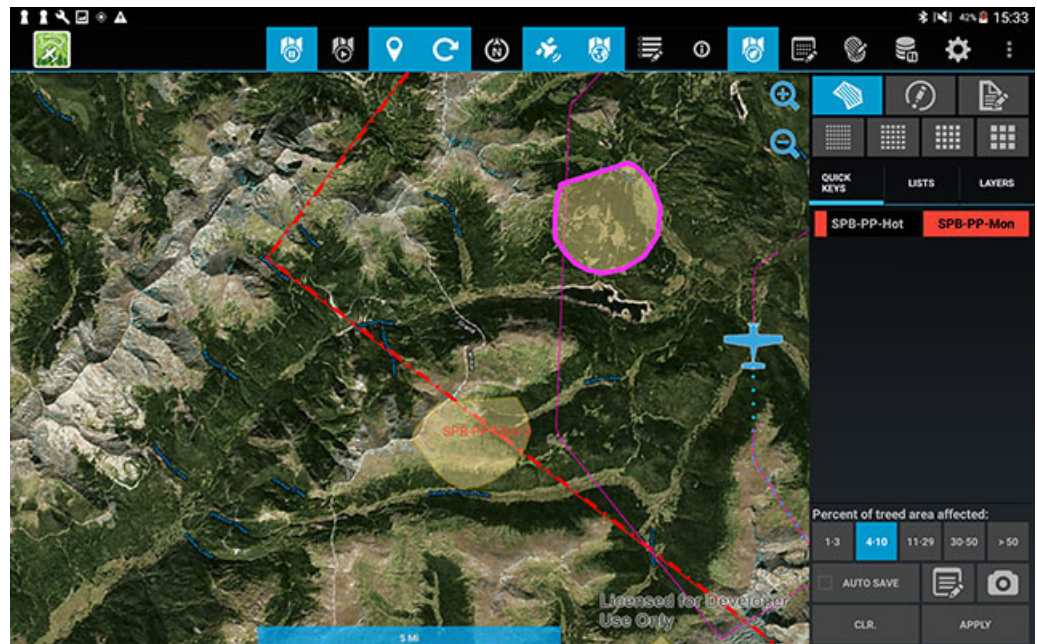


Photo of the Digital Mobile Sketchmapping System (DMSM) used to record tree mortality and damage data

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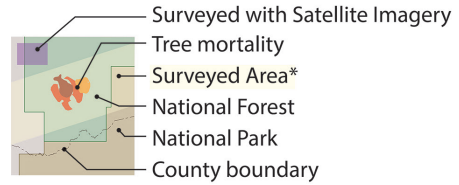
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FOREST HEALTH PROTECTION AERIAL DETECTION MONITORING

2021 SURVEY

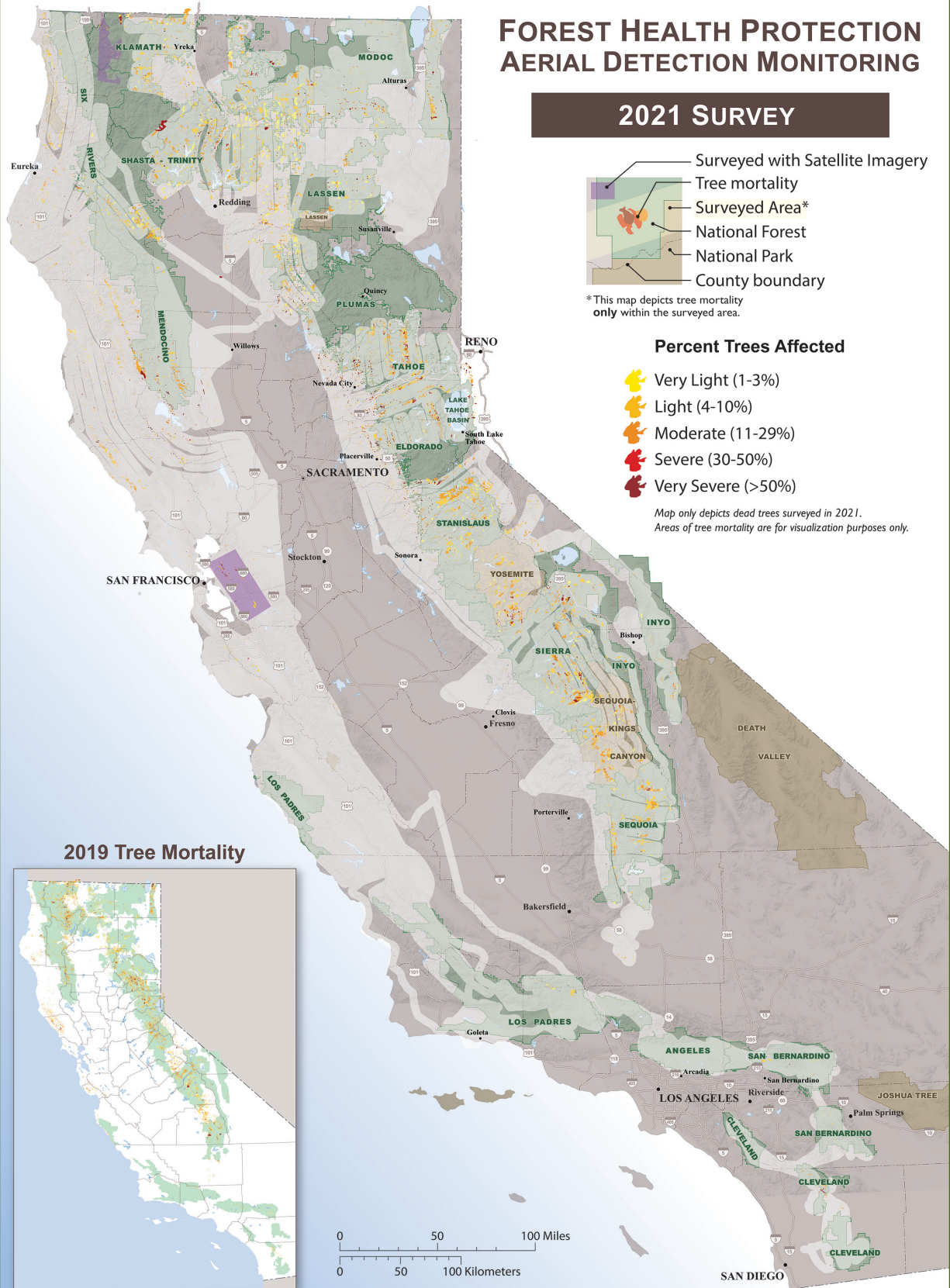


*This map depicts tree mortality only within the surveyed area.

Percent Trees Affected

- Very Light (1-3%)
- Light (4-10%)
- Moderate (11-29%)
- Severe (30-50%)
- Very Severe (>50%)

Map only depicts dead trees surveyed in 2021.
Areas of tree mortality are for visualization purposes only.



2019 Tree Mortality

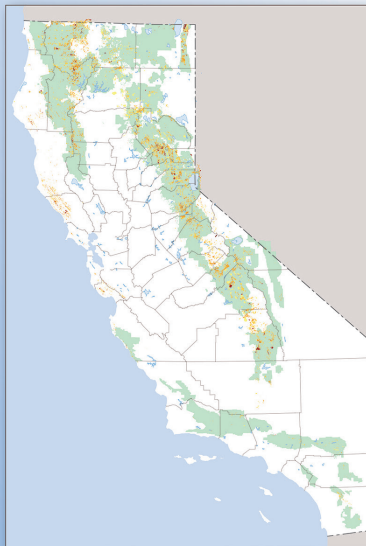


Figure 1. Statewide damage mapped via aerial detection survey in 2021.

Overview

The US Forest Service (USFS), Pacific Southwest Region, State and Private Forestry staff conduct annual aerial surveys throughout forested areas of California to detect tree mortality and tree damage, such as defoliation or branch flagging. Surveys are flown in small, fixed-wing aircraft on a 4–5-mile grid pattern with 2 observers recording from opposite sides of the plane. Most National Forests and Parks in California are surveyed, along with other federal, state, and private lands.

For the 2021 flight season, approximately 38 million acres were surveyed between July and October.

Due to multiple large wildfires that burned from several weeks to months, several areas were not covered by normal aerial survey operations. In addition, areas that burned in the 2019 and 2020 fire seasons were largely not surveyed because recent insect and disease activity is difficult to detect in such areas.

Some of these areas not flown in 2021 were instead observed with “scan and sketch” remote sensing methods developed during 2020 when flights did not occur due to COVID travel restrictions. Approximately 146,000 acres were surveyed in this way within the Shasta-Trinity National Forest. These areas of interest (AOIs) were virtually surveyed by 3 forest health specialists utilizing portable touch tablets equipped with compatible ADS software to digitize points and polygons of disturbance. Satellite imagery was acquired on September 23rd, 2021. Additionally, a special request for “Scan and Sketch” to cover the East Bay mortality event in early 2021 was carried out over 82,000 acres by 1 surveyor using imagery acquired between August 15th and October 6th, 2020 from WorldView-2, WorldView-3, and GeoEye-1 satellites, pansharpened to 30-50cm resolution, and were acquired from Maxar Technologies under the U.S. Government’s EnhancedView Program. These detections are included in totals below.

Elevated levels of tree mortality were recorded on 1.3 million acres, totaling an estimated 9.5 million dead trees, mostly fir, followed by ponderosa pine. Most of the mortality can likely be attributed to the lingering effects of the 2012-2016 exceptional drought and subsequent successful bark and engraver beetle attacks that have now resulted in ~173 million dead trees since 2010 (see Fig. 2). Another exceptional drought period began in 2020 and worsened in 2021. Detected mortality in 2020 was again concentrated in higher elevations of the southern Sierra Nevada Range; however, activity has also significantly increased in central and, to a lesser extent, northern areas (see Fig. 1).

Since ADS was not conducted 2020 (see the [2020 Final ADS report](#) for more information), trends in mortality will be discussed below by comparing 2021 to 2019 data.

Background

Based on the May water conditions reports from the California Department of Water Resources, since 2006 the state has been in a drought situation for all years all but 2010, 2011, 2016, 2017 and 2019. This prolonged water deficit has had profound impacts on California forests, killing trees outright and predisposing them to insect outbreaks and other damage agents. California has had significantly elevated amounts of forest tree mortality since 2015 (see Fig. 3).

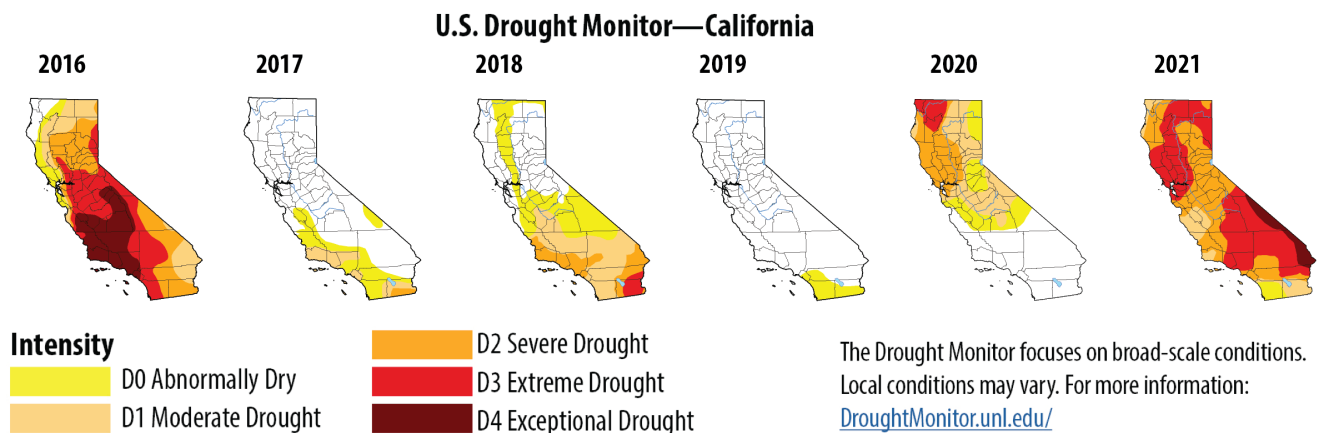


Figure 2. The U.S. Drought Monitor maps of 2016 through January 2021 illustrate the severity of the drought event in California. Maps are presented from the report date in April of each year. D1 is the least intense drought level and D4 the most intense; D0 areas are not in drought. A full description of each drought severity classification is available from the U.S. Drought Monitor website. Source: U.S. Drought Monitor

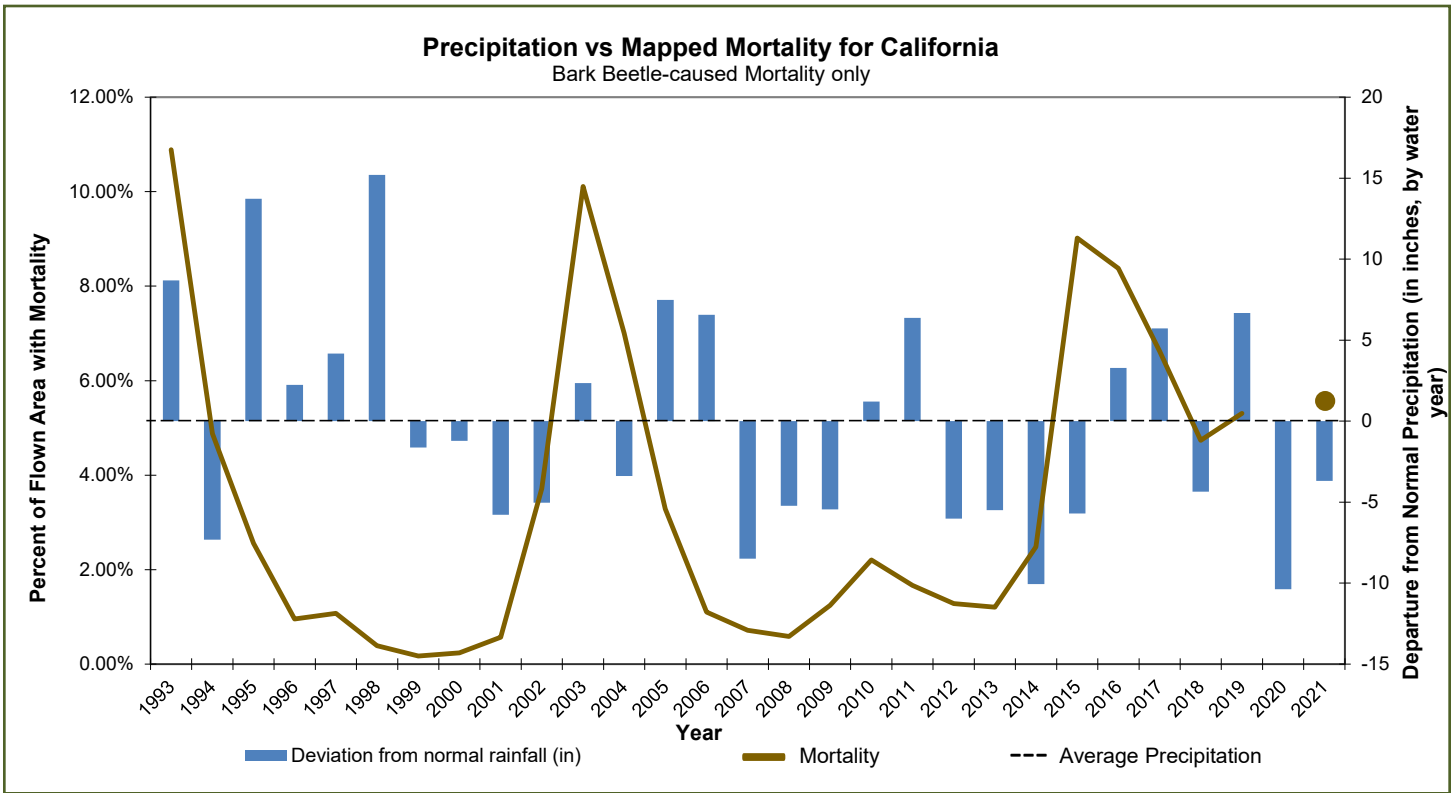


Figure 3. This chart shows the long-term trends in tree mortality and precipitation variability in California since 1993. There is a break in tree mortality data for 2020 because aerial survey was not flown that year due to COVID-19 restrictions.

In 2019, ADS detected areas of greatly elevated mortality of California red fir, particularly in higher elevation areas of the southern Sierra Nevada Range and in white fir wherever forests were dense. Top kill was also common. Fir mortality in particular has shifted in recent years to higher elevations and more northern areas. Additionally, in 2019, tanoak mortality associated with sudden oak death remained elevated as a result of a wet spring event in 2017.

According to the US Geological Survey, the statewide 2020-2021 water year was the 3rd driest on record since January 1895. In 2020, northern California was mostly in moderate to severe drought situation. In 2021, California experienced the most intense exceptional drought on record, with central portions of the State being the most severely impacted (see Fig 2). Overall statewide precipitation in 2021 was 50% of average.

Though no ADS was conducted in 2020, other RS efforts did indicate continued elevated mortality at least for the areas covered and thus it can be surmised that regional mortality was likely also generally elevated.

Highlights

Acres reported below may be noted in more than one bullet, as multiple damaging agents often occur in the same location. Additionally, although acres reported had some level of damage, not all host trees in any given acre were killed or damaged. The numbers of acres and trees below are rounded as appropriate.

Bark Beetles and Wood Borers

Fir mortality attributed to fir engraver beetle (*Scolytus ventralis*) comprised over 64% of the total tree mortality observed in 2021. Approximately 6.1 million dead firs were recorded across 780,000 acres, compared to 12.4 million dead fir trees across 1.9 million acres in 2019. Although mortality has decreased from 2019 levels, fir mortality remains elevated throughout most of the Region.

Fir mortality attributed to fir engraver beetle:

- California and Shasta red fir (*Abies magnifica*) mortality was widespread throughout its range and typically of light to moderate intensity. However, severe levels of mortality were also detected in many areas, particularly the central Sierra Nevada Range such as high elevation areas of the Stanislaus NF (see Fig. 1). An estimated 4.5 million trees across 500,000 acres died, a decrease from the ~8 million trees across 1 million acres in 2019.

- White fir (*Abies concolor*) mortality was widespread throughout its range but typically at light intensities and correlated with dense forest conditions. Mortality was particularly widespread and generally more severe within the Klamath and Shasta-Trinity NFs and the Warner Mtns (see Fig. 1). An estimated 1.6 million trees across 290,000 acres died, compared to 4.8 million trees across 860,000 acres in 2019.

Note: Red and white fir often occur together in mixed conifer mid-elevation stands and can be difficult to differentiate from the air.

Pine mortality attributed to mountain pine beetle (*Dendroctonus ponderosae*) remained elevated with ~380,000 dead trees across 44,000 acres in 2021 compared to an estimated 552,000 dead trees across 57,000 acres in 2019.

- Whitebark pine (*Pinus albicaulis*) mortality increased from ~143,000 trees across 15,000 acres in 2019 to 270,000 trees across 31,000 acres in 2021. Mortality was common in the Sierra Nevada Range from the Stanislaus NF south to Sequoia/Kings-Canyon National Park.
- Lodgepole pine (*Pinus contorta*) mortality decreased from an estimated ~278,000 trees across 28,000 acres in 2019 to 98,000 trees across 12,000 acres. Mortality was particularly heavy along the Sierra Crest west of Mono Lake.
- Sugar pine (*Pinus lambertiana*) mortality increased from ~2,000 trees across 490 acres in 2019 to 4,000 trees across 480 acres in 2021. Mortality was widely scattered and mostly in single trees and small groups.
- Limber pine (*Pinus flexilis*) mortality decreased from ~41,000 trees across 4,100 acres in 2019 to 3,000 trees across 660 acres in 2021. Areas of moderate activity occurred near June Lake and in the White Mtns.
- Western white pine (*Pinus monticola*) mortality decreased from ~88,000 trees across 12,000 acres in 2019 to 190 trees across 210 acres in 2021. Most of this occurred east of Dardanelle within the Stanislaus NF.

Pine mortality attributed to western pine beetle (*Dendroctonus brevicomis*) increased from an estimated 793,000 dead trees across 124,000 acres in 2019 to ~2.1 million dead trees across 300,000 acres in 2021. Ponderosa pine (*Pinus ponderosa*) accounted for 99% of this mortality. Mortality was most widespread in the Klamath and Shasta-Trinity National Forests; however, it was most intense in the Tahoe and Stanislaus NFs.

- Coulter pine (*Pinus coulteri*) mortality decreased from ~2,000 trees across 170 acres in 2019 to 260 trees across 20 acres in 2021. Mortality was widely scattered in small groups, but one larger area of mortality occurred on the southern flank of Mount Diablo.

Jeffrey pine (*Pinus jeffreyi*) mortality attributed to Jeffrey pine beetle (*Dendroctonus jeffreyi*) decreased from ~179,000 dead trees across 67,000 acres in 2019 to 122,317 dead trees across 26,082 acres in 2021. Mortality was widespread but was particularly severe and extensive in the Mammoth Lakes area.

- Jeffrey pine (*Pinus jeffreyi*) tree mortality attributed to ips (*Ips* spp.) in and around the northeast portions of the Mt. Pinos Ranger District, Los Padres National Forest remained elevated with ~11,000 dead trees across 5,000 acres in 2021, compared to ~11,000 dead trees across 3,000 acres in 2019.

Goldspotted oak borer (*Agrilus auroguttatus*)-related oak (*Quercus* spp.) mortality mostly in San Diego County increased in 2021 to approximately 19,000 dead trees across 4,000 acres, up from ~17,000 dead trees across 11,000 acres in 2019. Three severe concentrations were detected near the Palomar Ranger District and Lake Henshaw, accounting for over half of the total mortality recorded in 2021, resulting in lower total acres with mortality compared to 2019.

Knobcone pine (*Pinus attenuata*) mortality attributed to California flatheaded borer (*Melanophila californica*), although multiple agents are likely involved, increased from ~14,000 trees across 2,400 acres in 2019 to ~95,000 trees across 8,000 acres in 2021. Mortality was most common in the central Klamath NF, the south shore of Clear Lake, and in the Snow Mountain area of the Mendocino NF.

Douglas-fir (*Pseudotsuga menziesii*) mortality (not attributed to tree damage caused by spring bear feeding) increased in 2021 with an estimated 170,000 dead trees across 18,000 acres, compared to ~127,000 dead trees across 27,000 acres in 2019. Scattered mortality was common throughout most of the northern coastal range and, to a lesser extent, in the northern interior.

Pinyon pine (*Pinus monophylla*) mortality attributed to ips (*Ips* sp.) increased from an estimated 5,600 dead trees across 10,000 acres in 2019 to 60,000 dead trees across 8,400 acres in 2021. Mortality was concentrated primarily in the White Mountains in both Inyo and Mono counties.

Gray pine (*Pinus sabiniana*) mortality increased from an estimated 750 dead trees across 30 acres in 2019 to 53,000 dead trees across 4,200 acres in 2021. Mortality was evident throughout the foothills of both the Sacramento and San Joaquin valleys.

Mortality Due to Diseases

Tanoak (*Notholithocarpus densiflorus*) mortality attributed to sudden oak death SOD (*Phytophthora ramorum*) decreased to an estimated 97,000 dead oak trees across 16,000 acres, compared to ~885,000 dead trees across 92,000 acres in 2019. Spread of SOD is greatly curtailed in times of drought. Substantial tanoak mortality not attributed to SOD was also recorded outside of known SOD infected areas.

Monterey pine (*Pinus radiata*) mortality also increased from an estimated 35 dead trees to ~5,500 dead trees across 680 acres and mostly attributable to chronic pitch cankers and other diseases combined with drought. Mortality was particularly active in the eastern Bay Area west of Danville.

Mortality Attributed to Drought

Suspected oak mortality was observed in many areas, especially the foothills of the Southern Sierra Nevada Range; however, ADS was unable to determine if the trees were dead or exhibiting an early leaf drop or die-back as a response to drought.

ADS detected ~75, 000 dead trees across 3,700 acres of hardwoods, particularly acacia (*Acacia* spp.) and eucalyptus (*Eucalyptus* spp.), in the East Bay Area. Ground inspections indicate that chronic cankers and other diseases, along with dense forest conditions, were predisposing factors.

Defoliation/Dieback

Defoliation of quaking aspen (*Populus tremuloides*), typically attributed to Marssonina leaf blight (*Marssonina* spp.), was observed on only 500 acres in Mono County, by far the lowest in recent years.

Defoliation of pinyon pine (*Pinus monophylla*) was observed on approximately 1,800 acres in the White Mountains, Inyo National Forest, attributed to pinyon needle scale (*Matsucoccus acalyptus*).

Severe defoliation of lodgepole pine (*Pinus contorta*) by lodgepole pine needleminer (*Coleotechnites milleri*) was again concentrated in and around eastern Yosemite National Park and detected on approximately 8,500 acres, down from ~12,000 acres recorded in 2019 and.

Severe defoliation of Sitka spruce (*Picea sitchensis*) due to spruce aphid (*Elatobium abietinum*) was detected on approximately 60 acres, down from 1,250 acres recorded in 2019. The activity occurred south of Ferndale along the North Coast.

Acres with Mortality and Estimated Number of Dead Trees by Forest (2021)

National Forest	Acres	Dead Trees
Angeles National Forest	38	400
Cleveland National Forest	3,000	16,000
Eldorado National Forest	26,000	290,000
Humboldt-Toiyabe National Forest	26,000	279,000
Inyo National Forest	64,000	544,000
Klamath National Forest	76,000	745,000
Lake Tahoe Basin Management Unit	4,000	70,000
Lassen National Forest	67,000	275,000
Los Padres National Forest	5,000	16,000
Mendocino National Forest	30,000	450,000

National Forest	Acres	Dead Trees
Modoc National Forest	51,000	435,000
Plumas National Forest	12,000	141,000
San Bernardino National Forest	5,000	15,000
Sequoia National Forest	63,000	377,000
Shasta-Trinity National Forest	199,000	1,209,000
Sierra National Forest	89,000	861,000
Six Rivers National Forest	8,000	50,000
Stanislaus National Forest	95,000	587,000
Tahoe National Forest	79,000	997,000

The numbers of acres and trees throughout this report have been rounded as appropriate.

Acres with Mortality and Estimated Number of Dead Trees by County (2021)

County	Acres	Dead Trees
Alameda	2,000	15,000
Alpine	44,000	332,000
Amador	5,000	116,000
Butte	12,000	79,000
Calaveras	24,000	168,000
Colusa	9,000	132,000
Contra Costa	3,000	68,000
Del Norte	11,000	46,000
El Dorado	17,000	156,000
Fresno	109,000	935,000
Glenn	2,000	14,000
Humboldt	31,000	194,000
Inyo	10,000	68,000
Kern	5,000	25,000
Lake	21,000	331,000
Lassen	28,000	130,000
Los Angeles	24	400
Madera	19,000	249,000
Marin	500	5,000
Mariposa	30,000	211,000
Mendocino	37,000	315,000
Merced	300	1,000
Modoc	36,000	337,000
Mono	39,000	354,000
Monterey	1,000	3,000
Napa	100	1,000
Nevada	20,000	248,000
Orange	100	1,000

County	Acres	Dead Trees
Placer	35,000	452,000
Plumas	8,000	50,000
Riverside	1,000	5,000
San Benito	2	62
San Bernardino	4,000	10,000
San Diego	4,000	20,000
San Luis Obispo	200	4,000
San Mateo	300	3,000
Santa Barbara	100	2,000
Santa Clara	3,000	19,000
Santa Cruz	200	1,000
Shasta	125,000	666,000
Sierra	36,000	454,000
Siskiyou	195,000	1,295,000
Solano	400	3,000
Sonoma	12,000	78,000
Tehama	36,000	176,000
Trinity	82,000	572,000
Tulare	115,000	816,000
Tuolumne	61,000	300,000
Ventura	4,000	11,000
Yolo	3	79
Yuba	2,000	22,000

The numbers of acres and trees throughout this report have been rounded as appropriate.