Forest Service
United States Department of Agriculture

Oregon Department of Forestry
Forest Health

Pacific Northwest Region

Forest Health Highlights in Oregon - 2022

FOREST HEALTH HIGHLIGHTS IN OREGON - 2022

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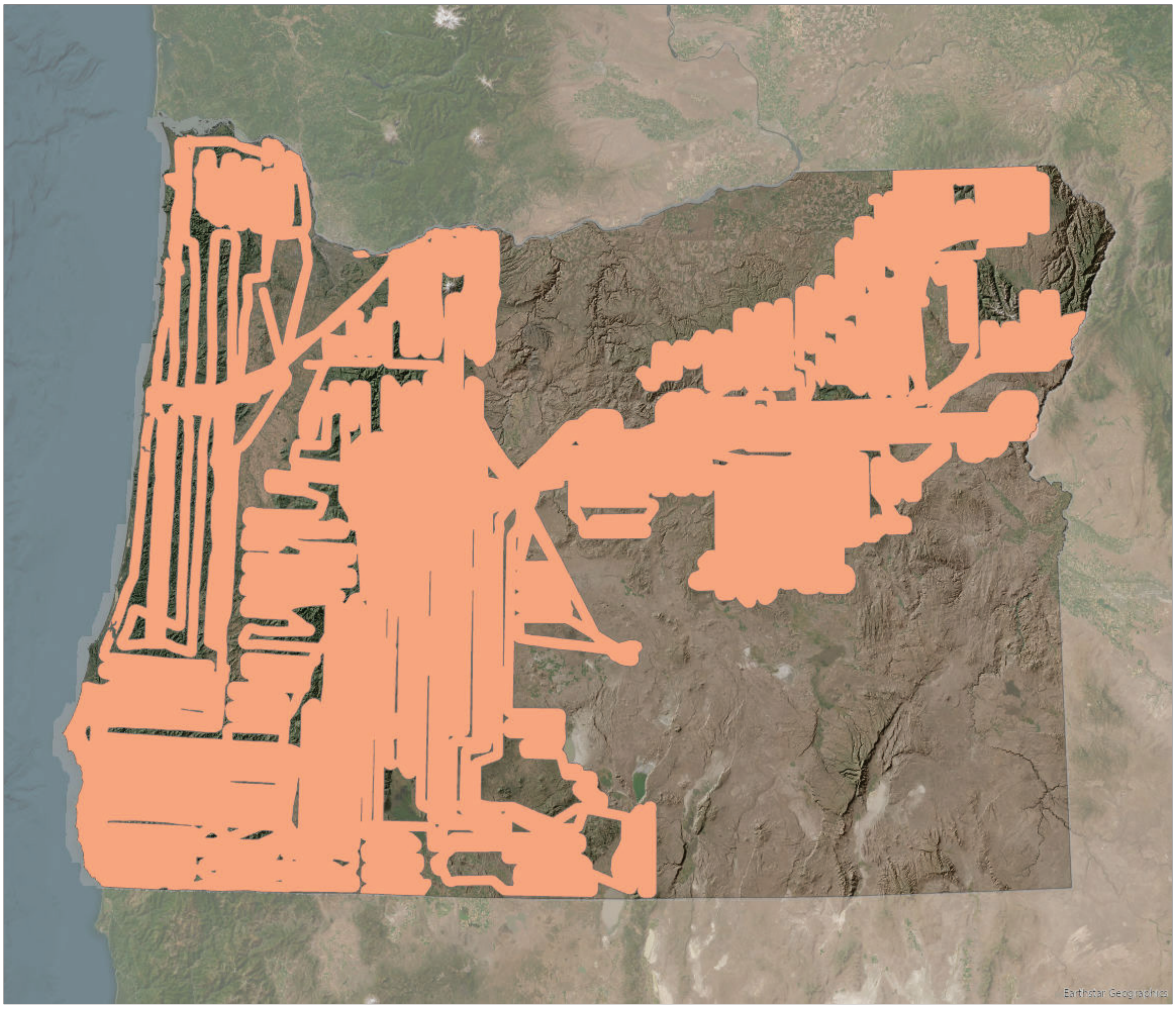
Cooperative Aerial Survey: 2022 coverage area



Map above: In 2022 the cooperative USFS and ODF *aerial survey covered 33 million acres.*

Front cover: *Historic levels of true fir mortality were observed in 2022, as a result of ongoing hot droughts, and in some areas, a combination of drought, root disease, and attacks from fir engraver beetle and balsam woolly adelgid (Danny DePinte, USFS).*

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LANDOWNER RESOURCES

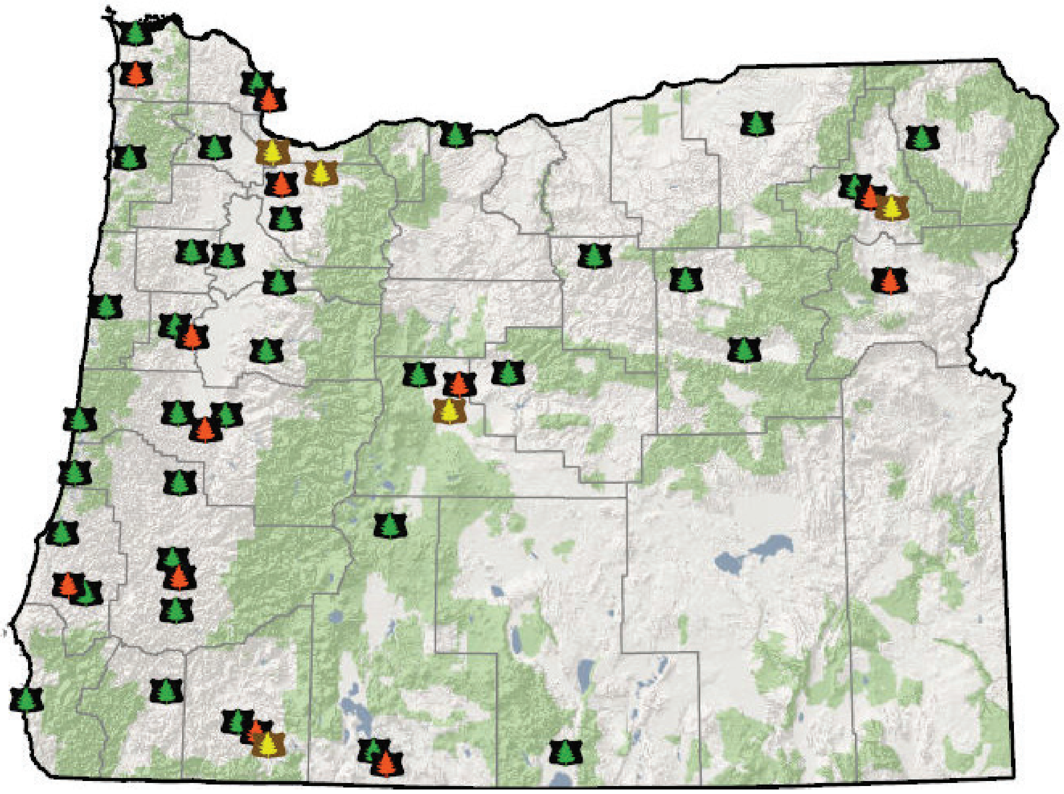


Figure 1. Map of ODF (black badge with green tree), USFS (brown badge with yellow tree), and OSU (black badge with orange tree) unit offices.

OREGON DEPARTMENT OF FORESTRY (ODF):

Connect with your local ODF stewardship forester to get stand management guidance, diagnose and troubleshoot issues, and learn about incentive programs: https://tinyurl.com/ODF-forester

Connect with the ODF Forest Health team to diagnose and manage abiotic stressors, insects, diseases, weeds, and other invasive species. Visit the ODF Forest Health website for fact sheets and training videos: https://tinyurl.com/odf-foresthealth

USDA FOREST SERVICE (USFS):

(Federal agencies and Tribes only) Connect with USFS Forest Health Protection specialists to diagnose and manage abiotic stressors, insects, diseases, weeds, and other invasive species: https://www.fs.usda.gov/goto/r6/foresthealth

OREGON STATE UNIVERSITY (OSU) FORESTRY EXTENSION SERVICE:

Connect with your local OSU Forestry Extension agent to get stand management guidance and to diagnose and troubleshoot forest health issues: https://tinyurl.com/OSU-forester

FORESTRY IN OREGON

Forestry has a long and storied history in the Pacific Northwest, especially in Oregon which, at 63 million acres, is almost 50% forestland. These numbers have remained unchanged since 1953. These forests vary from: family-owned forests that are handed down across generations; large tracts of productive industrial land; and untouched wilderness. Oregon offers a diversity of forests ranging from mossy, rain-drenched coastal ecosystems to arid ecosystems of central Oregon to part-year snow-covered high elevations along the Cascades and northeast mountain ranges (Fig. 2). Oregon's forests consist of federal (60%), private (35%), state (3%), tribal (1%), and other public (1%) ownerships.

Western Oregon is characterized by high rainfall and dense coniferous forests along the Pacific coastline, the Coast Range, and western slopes of the Cascade Range. Eastern Oregon largely consists of lower density, semi-arid forests and higher elevation desert. Oregon forests are primarily dominated by conifers such as Douglas-fir, true fir, western redcedar, western hemlock, lodgepole and ponderosa pine, among others. The most abundant hardwoods are bigleaf maple, red alder, Oregon white oak, and black cottonwood.

Figure 2. Diversity of Oregon forests (Christine Buhl, ODF).

Oregon strives to ensure that timber production is sustainable and limits negative impacts to our natural resources. Oregon was first in the nation to create laws regulating forest practices. The Forest Practices Act (FPA, OAR 629 Est. 1971) guides non-federal, public, and private landowners on how best to manage their forestlands to preserve ecosystem function and resilience while utilizing this renewable resource. A comprehensive overhaul of the FPA began in 2021 when representatives for conservation groups, timber industries, and small woodland owners held mediated discussions to recommend new wildlife resource protection standards for non-federal forestlands. These changes were presented in a legislative package, the Private Forest Accord (SB 1501 & 2, HB 4055), which was passed in early 2022.

Federal lands are managed under Northwest Forest Plan policies (Est. 1994) and some private forest landowners follow additional growth and harvest requirements as part of various certification programs (e.g., Sustainability Forestry Initiative, American Tree Farm System, Forest Stewardship Council, etc.).

In recent years Oregon forests have been pushed to the limit due to climate change and initiatives have been created to address this ongoing issue. Efforts to address climate change impacts on forestry, e.g., reducing carbon loss and increasing carbon capture, include the USFS Climate Change Roadmap for federal lands and the ODF Climate Change and Carbon Plan for non-federal lands.

2022 FOREST HEALTH SUMMARY

Abiotic, insect, and disease disturbance agents can cause significant tree mortality, growth loss, and damage in Oregon forests each year. Many insects and diseases are native and widely present on the landscape and only present a problem when tree defenses are reduced. Often a complex of factors contribute to tree stress and weakened defenses (Manion 1991 decline spiral model). Insects and diseases can play a critical role in maintaining healthy, functioning forests by weeding out unhealthy trees, contributing to decomposition and nutrient cycling, and creating openings that enhance forest diversity and wildlife habitat. **A healthy forest is dynamic and includes insects, diseases, and natural wildfire cycles. However, in recent years climate change impacts such as ongoing hot droughts have increased susceptibility to opportunistic insect and disease agents.**

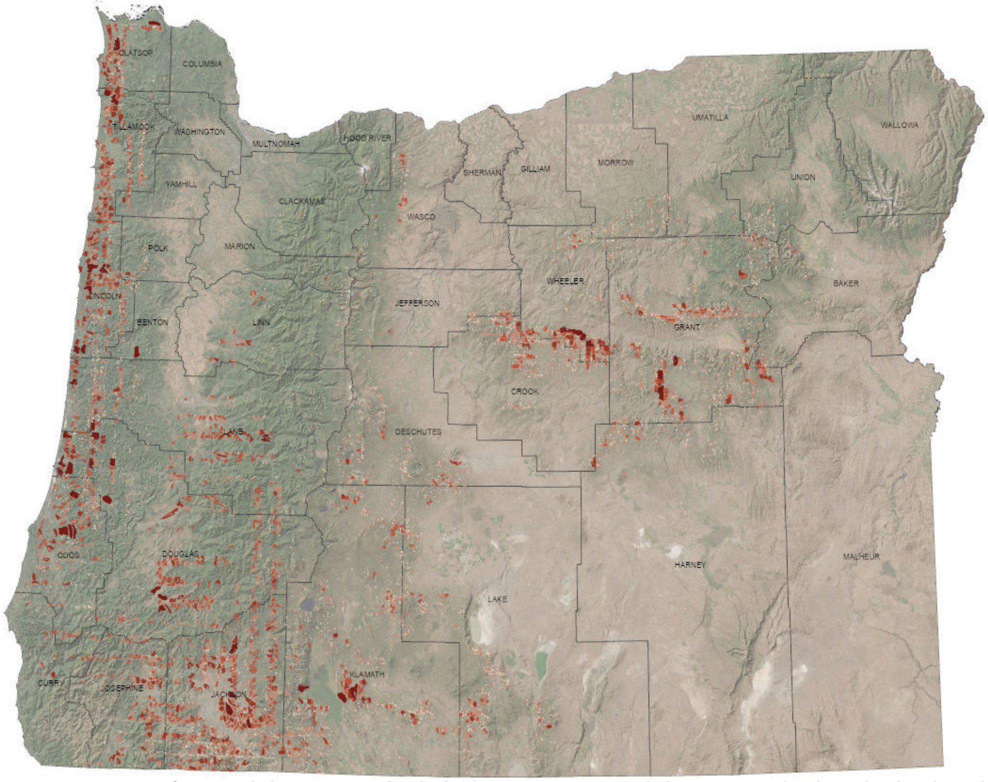


Figure 3. "Heat map" of acres with damage/mortality (red indicates many acres with damage/mortality, lower levels indicated in orange) as caused by insects, diseases, and abiotic (excluding wildfire) agents as identified by the 2022 aerial survey.

This report highlights major agents of damage and mortality in Oregon forests over the past year and provides updates on chronic issues. Much of this information is typically obtained from aerial and ground surveys and monitoring traps. We also rely on reports from ODF, USFS and OSU forestry staff from offices around the state (page 1 and back cover) as well as from public and private forest landowners and land managers, and members of the general public. Damage and mortality trends (Fig. 5) and maps (Figs. 3 & 6) obtained from a combination of aerial survey data (Fig. 4) and site visits indicate that hot drought stress is one of the main underlying causes of tree dieback and decline - often followed by subsequent attack by opportunistic insects such as bark beetles. Landscape-level stress conditions from droughts produce a pulse of weakened trees that lend themselves to bark beetle population outbreaks that may spill over into healthy trees. Another widespread stressor that weakens trees and further predisposes them to the effects of droughts and reduces resilience to insects is root disease. Although root diseases can persist and impact trees for many years, they are hard to detect via aerial surveys and require extensive ground surveys to detect and evaluate. Going forward we must incorporate projections of changing climate when deciding tree species placement and density, to give trees the best chance of long-term success. Aerial surveys identified the largest amounts of tree damage and mortality in areas that have been enduring the highest levels of persistent drought (Fig. 3).

2022 FOREST HEALTH SUMMARY

In 2022, we continued to see the negative direct and indirect impacts of persistent droughts. Historic levels of tree mortality, specifically in true fir species (over 1 million acres with true fir mortality) were observed across the state. True fir species are some of our least drought-tolerant conifers and in some areas, years of wildfire suppression have allowed them encroach into areas that cannot sustain them in a changing climate. True fir mortality is marked in surveys as "fir engraver" (bark beetle) to maintain historical consistency, however, this mortality is known to result from a complex of factors typically starting with damage from drought and/or root disease and ending with fir engraver beetles and, in some areas, balsam woolly adelgid.

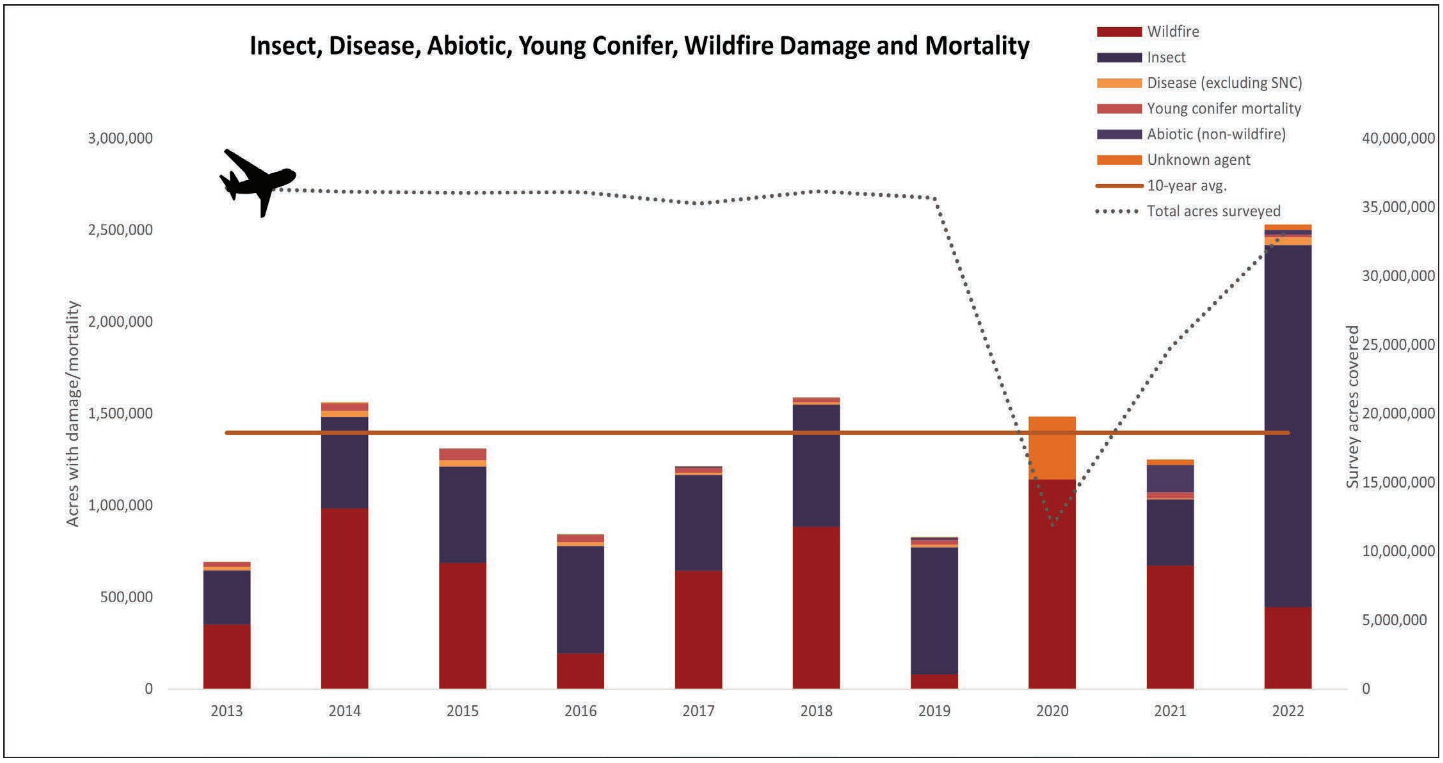
There are some caveats to the aerial survey data shown in our tables, figures and maps. Data obtained via aerial survey are not comprehensive but it can give a long-term, watershed-scale overview of trends across Oregon. Damage from some agents, such as diseases, is not fully captured via aerial survey and other damage may be missed due to the timing of the survey. Comparison of trends across years has also been complicated by disruptions to normal data collection that has resulted in fewer acres being flown in 2020 (altered data collection process due to COVID-19 safety measures) and in 2021 (staffing shortages and wildfire disruption).

In 2022, we observed over 2.7 million acres of damage and mortality from insects, diseases and non-wildfire abiotic stressors (Fig. 4). This total was 70% higher than the 10-year average (note, this figure stays about the same when we remove 2020 and 2021 data which covered a smaller footprint and thus observed less damage). In 2022, as with most years, cumulative totals for acres with damage from non-wildfire abiotic stressors, insects, diseases are higher than those for wildfire damage. In some years, acres with insect-caused tree mortality (often paired with underlying drought stress) is comparable or even higher than acres with wildfire-caused tree mortality. Luckily, management strategies to promote tree resilience and maintain stand health also combat mortality from drought stress, insect infestation, and high intensity wildfires.

As noted above, many diseases such as foliar and root diseases are not easily observable via our general aerial surveys. However some diseases totals are captured: the "young conifer mortality" survey (prev. "bear" survey) has been shown to reflect as much as 80% root disease as the causal agent (Taylor et al. 2019), specialty surveys that are flown in addition to the general survey to observe pathogens that cause Swiss needle cast (flown every other year) and Sudden Oak Death (multiple flights a year).

Acres with tree damage / mortality											
Year	**Unknown agent**	**Abiotic (non-wildfire)**	**Young conifer mortality**	**Disease (excluding SNC)**	**Insect**	**Wildfire**	**Total (excluding wildfire)**	**Total**	**10-year avg. (excluding wildfire)**	**10-year avg.**	**Total acres surveyed**
2013	3,036	238	24,925	19,452	296,180	350,786	343,831	694,617	788,178	1,396,184	36,409,942
2014	6,105	75	39,111	32,963	497,206	984,629	575,460	1,560,089	788,178	1,396,184	36,131,000
2015	3,007	2,976	59,121	34,538	527,088	685,809	626,730	1,312,539	788,178	1,396,184	36,027,078
2016	3,245	51	40,047	21,199	586,960	192,557	651,501	844,058	788,178	1,396,184	36,099,637
2017	635	4,811	29,072	9,998	523,208	644,141	567,724	1,211,865	788,178	1,396,184	35,263,946
2018	240	2,128	22,072	11,910	666,214	883,338	702,565	1,585,903	788,178	1,396,184	36,151,968
2019	4,448	13,625	25,841	12,311	694,066	78,989	750,292	829,281	788,178	1,396,184	35,672,506
*2020**	*343,138*					*1,141,613*	*343,138*	*1,484,751*	*788,178*	*1,396,184*	*11,905,453*
2021	29,332	149,733	34,756	4,863	360,322	672,345	579,006	1,251,351	788,178	1,396,184	24,782,940
2022	27,879	26,016	14,480	41,043	1,974,746	445,858	2,741,530	3,187,388	788,178	1,396,184	33,418,549

Figure 4. Raw data obtained from 2013-2022 annual general aerial survey. Note, insect damage often indicates underlying stress from a different primary causal agent such as drought and some agents such as various diseases are not fully captured during surveys. In 2020, data were collected across a greatly reduced area via the Scan and Sketch method ("Scan and Sketch" in [2020 Forest Health Highlights]) and agents were difficult to verify and were thus combined as "unknown". Annual totals and 10-year averages are shown with and without the inclusion of wildfire acreage totals.



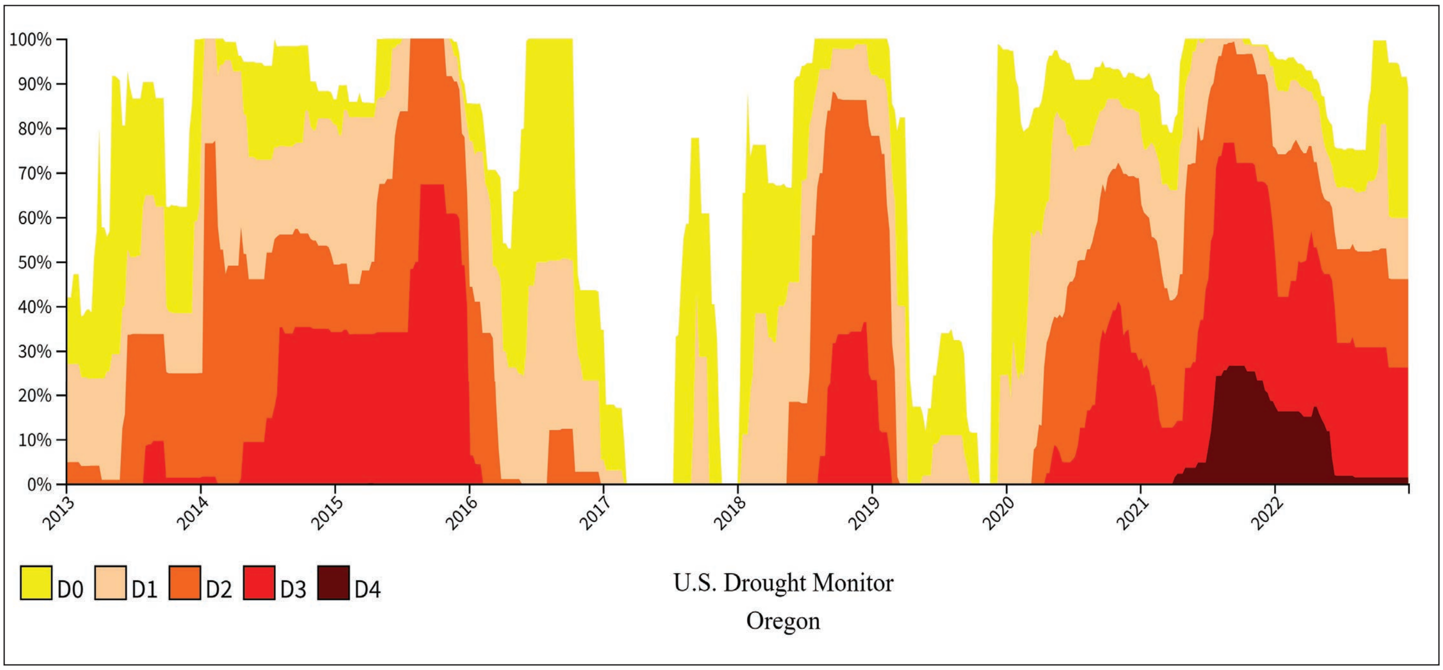


Figure 5. Top: 10-year trends in acres with damage from abiotic, insect and disease agents observed in the general aerial survey, as well as from wildfire damage. Note, all aerial survey metrics indicate acres "with" not "of" damage because undamaged trees are often intermixed within a mosaic of damaged and dead trees. Damage/mortality from some agents such as diseases is not shown here because they are either hard to observe via aerial survey or that data are collected via specialty surveys (e.g., Swiss needle cast and Sudden Oak Death surveys) that are not flown on the same annual schedule as the general survey. Data for those agents are detailed in the pathology section of this report (starting on page 28). Wildfire damage/mortality (data obtained from Northwest Interagency Coordination Center) is an influential factor on current and future forest health conditions and is shown, in addition to other forms of abiotic damage, for comparison. Wildfire trends are detailed starting on page 17.

Bottom: Average statewide drought trends for Oregon (U.S. Drought Monitor; Rankings are D0: abnormally dry, D1: moderate, D2: severe, D3: extreme, and D4: exceptional drought). Drought has been an underlying stressor to trees across the state for many years. Often there is a lagged response in tree damage/mortality of a year or more after drought events. Cause and effect comparisons can be made by between the figures above, in which tree mortality tends to increase in the years after increased drought levels. Sudden or prolonged droughts can be particularly damaging to trees.

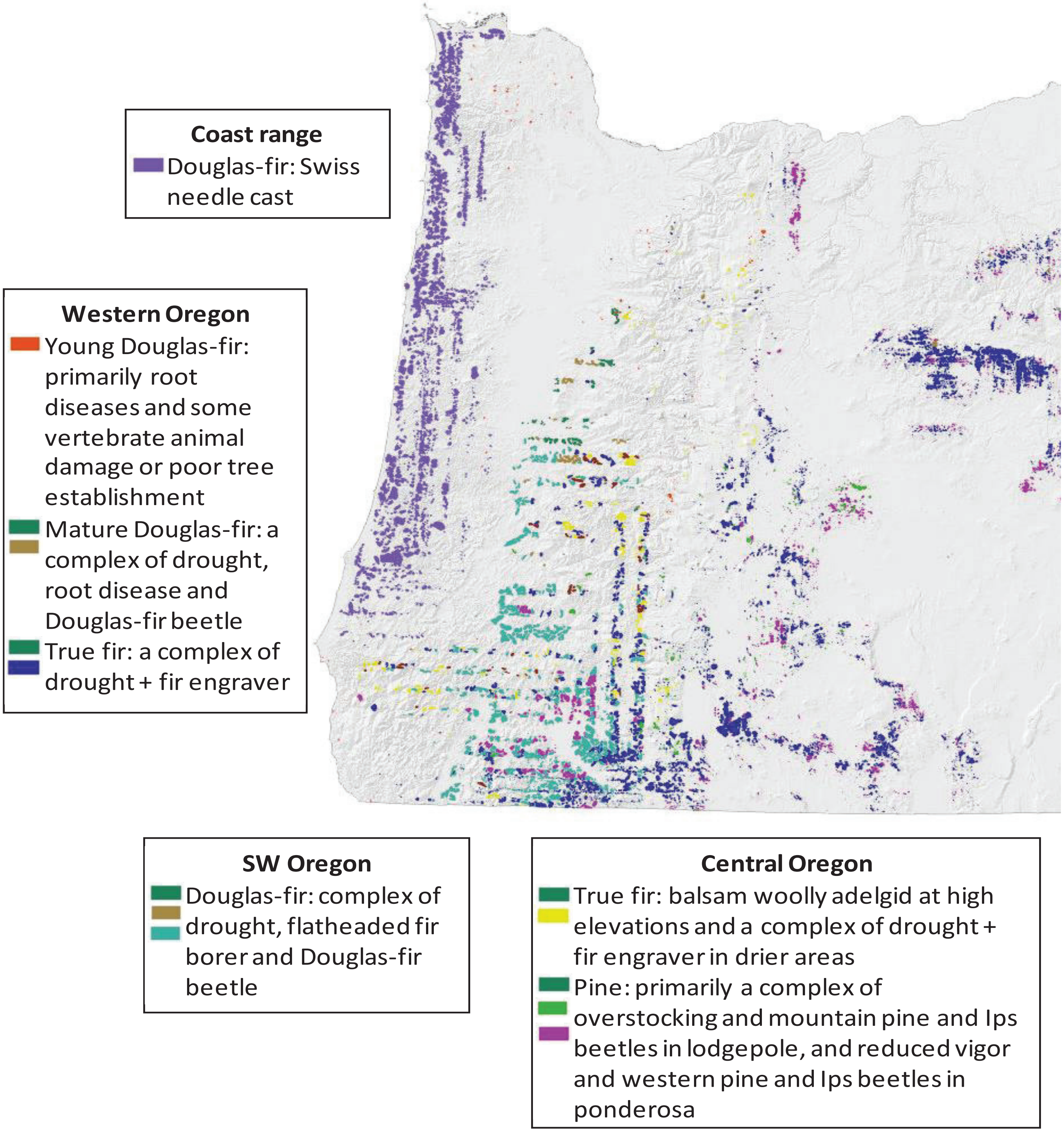
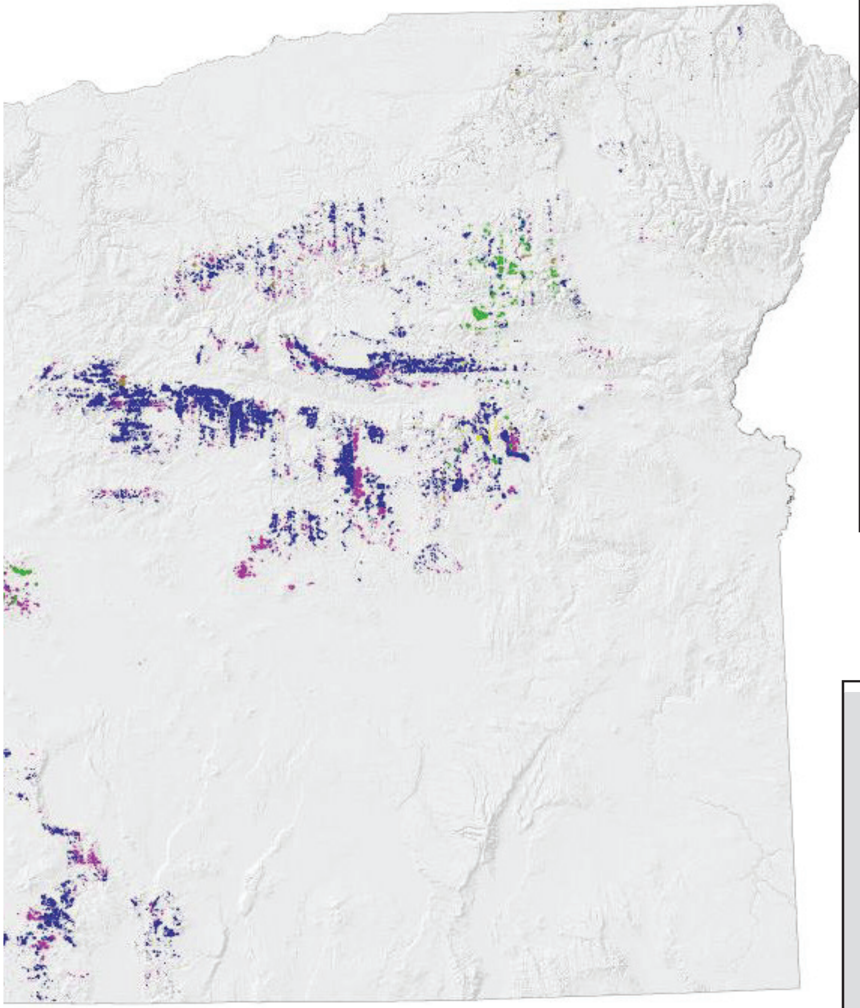


Figure 6. Map of tree damage and mortality as mapped by the 2022 general aerial survey and Swiss needle cast survey. Only the largest contributors to damage and mortality are shown. The most common primary and secondary agents of tree damage and mortality are listed for each region of the state. Often, tree mortality is a result of a complex of multiple different agents, starting with the most damaging and followed by less damaging agents that can only attack when tree defenses become exhausted.



Eastern Oregon

- Douglas-fir: spotty Douglas-fir tussock moth defoliation
- True fir: balsam woolly adelgid at high elevations and a complex of drought + fir engraver in drier areas
- Pine: primarily a complex of overstocking and mountain pine and Ips beetles in lodgepole, and reduced vigor and western pine and Ips beetles in ponderosa pine

Agents of tree mortality not captured via aerial survey:

- Root diseases
- Smaller-scale defoliators such as some fungal diseases and a few insect defoliators (larch casebearer, pandora moth, sawflies, etc.)
- Dwarf mistletoe
- Wildfire damage (more comprehensive data are available from the Northwest Coordination Center)

SURVEYS, MONITORING AND OTHER PROJECTS

Aerial Detection Survey (ADS)
In the 1940's there was a strong interest in maintaining timber economies, and growing concern for the health of our region's forests in relation to impacts on the timber supply. During the same time the aviation industry was developing. The combination of interests spawned creation of the region's aerial survey program that has been collecting data on forest damage from insects, diseases, abiotic and other stressors across Oregon and Washington for 75 years and counting.

Each year, USFS and ODF cooperatively conduct forest health surveys across all forested parts of the state to quantify tree damage and mortality from insects, diseases, and abiotic stressors (e.g., weather, climate, natural disasters). Wildfire damage from current year fires across all ownerships is captured more comprehensively by the Northwest Interagency Coordination Center and is included in our report's figures. Two observers board small fixed-wing aircraft, such as Cessnas, ODF's twin engine Partenavia, or USFS's Kodiak, and collect data using a Digital Mobile Sketch Mapping (DMSM) system (Fig. 7). Each observer records forest damage 1-2 miles out from their side of the plane and approximates the location and area of damage, intensity of damage, host tree species, and suspected damage agent(s).

During a typical survey season, the "general" forest health survey covers roughly 28 million acres with additional "specialty" surveys for damage agents that may not appear during the course of the general survey or are more sporadic such as: Swiss needle cast (SNC), sudden oak death (SOD), Pandora moth, oak looper, and invasive plants such as gorse. With these additional surveys, the agencies may cover a total of 35 to 41 million acres each year. In 2020, COVID-19 posed health risks to staff and survey was conducted via a different method (visually scanning high-resolution imagery of Oregon to map damage, see "Scan and Sketch" in 2020 Forest Health Highlights) In 2021, only 80% of the normal coverage area was surveyed due to disruption from wildfire and staffing shortages (See "Aerial Detection Survey" in 2021 Forest Health Highlights).

The 2022 season started with nearly normal operations despite staffing shortages and the general survey covered over 33 million acres (Fig. 8). The SNC survey, which is typically flown every other year but has been disrupted since 2018, was folded into the general survey due to weather delays. Aerial observers estimated 2.7 million total acres with damage in the general survey which comprised 7% of the total surveyed area. Historic levels of damage were seen in true fir. Recorded acres with damage (adjusted by area flown) increased over 200% from what was observed in 2021. This sudden increase in damage may be attributed to compounded impacts of chronic ongoing hot droughts, acute events such as scorch from the 2021 heat dome, and subsequent attack of weakened trees by opportunistic insects and diseases.

Although our data collection software is evolving to more accurately capture the amount of damaged trees we are reporting acres *with and not of* damage. Like wildfire, not all trees in the damage footprint are dead. The area of recorded damage represents a mosaic of live and dead trees. Teasing out tree species in mixed forests can also be difficult. Additionally, aerial sketch mapping survey work can be subjective to individual surveyors and data should be applied at a landscape level. Additional data for aerial surveys the past 75 years can be found on the USDA USFS ADS web page for Region 6; these data consist of products such as Disease Detection Survey Maps, IDS Geospatial Data, and IDS acreage summaries. The USFS recently created an ArcGIS Online story map and dashboard data summarizing the 2022 survey effort for Oregon and Washington.

ADS resources:
- ADS video: https://youtu.be/XPrKjWaoeeA
- ADS data, maps, storymap: https://tinyurl.com/FHAerialSurvey

Figure 7. Tree morality (left, circled in pink) is captured in DMSM software by drawing this area at the correct location on a Samsung tablet (right, circled in pink) (Christine Buhl, ODF).

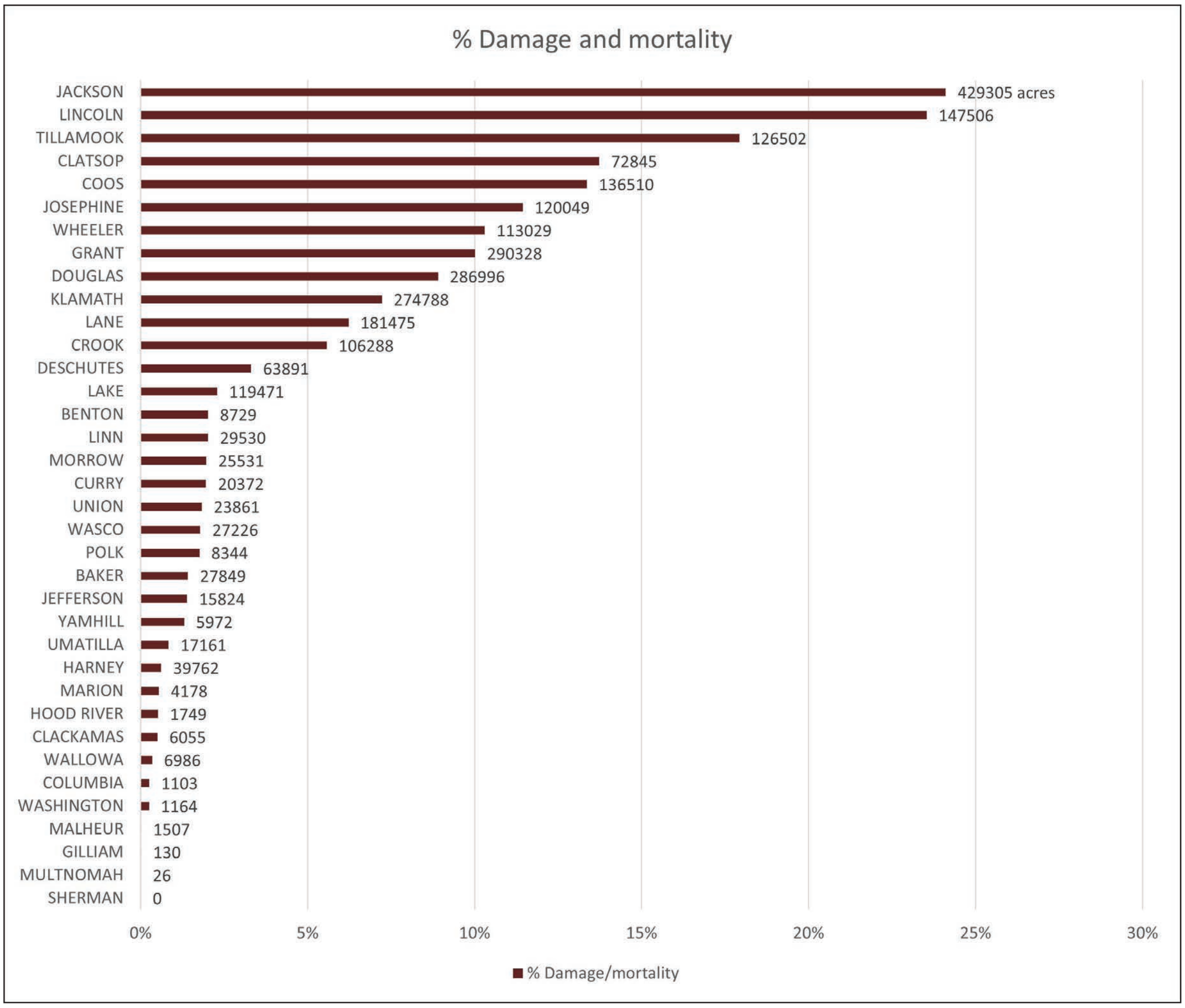


Figure 8. Percent forest damage and mortality by county as detected in the 2022 aerial survey. Bars indicate percent acres of damage relative to the size of the county (not limited to only forested portions). Labels indicate total number of damage / mortality for each county. The majority of the damage detected in Jackson county is related to drought, and the damage in Lincoln and Tillamook is related to Swiss Needle Cast.

SURVEYS, MONITORING AND OTHER PROJECTS

Hazard Tree

Pathologists with ODF and the USFS evaluate tree hazards and provide regular trainings to ensure that trees at risk of failure, due to root and stem rots or other defects, are removed to protect those working and recreating in the woods. ODF annually assesses state forest lands for hazards in recreation areas and assists the Oregon Parks and Recreation Department with hazard tree training to ensure that state parks have trained staff available to identify hazard trees.

Bark beetle landowner incentives cost share program

Each year, federal funds are allocated for bark beetle prevention and mitigation treatments such as thinning, pine slash management, and anti-aggregation pheromones. Some of these funds are applied on federal lands and others are allocated to ODF for non-federal landowners at a 1:1 match. In 2022, USFS applied bark beetle mitigation treatments on 2,235 acres on federal lands and ODF added another 29 acres across 4 non-federal ownerships. This cost share program may also support removal of living trees that were recently damaged by wildfire to prevent their subsequent infestation by bark beetles. Apply for cost share funds on non-federal lands: https://tinyurl.com/ODFcostshare

Douglas-fir tussock moth (DFTM) trapping

This ongoing monitoring trap system (Est. 1979) detects increases in moth numbers and can predict building outbreaks or determine status of current outbreaks of DFTM (Fig. 9) in eastern Oregon (see page 26).

Figure 9. DFTM larvae (Christine Buhl, ODF).

Oregon Forest Pest Detector program

Since 2013, the USDA-funded Oregon Forest Pest Detector (OFPD) program, coordinated and led by OSU Extension Forestry, has trained arborists, landscapers, park workers, and other professionals to identify the early signs and symptoms of priority invasive forest insects (http://pestdetector.forestry.oregonstate.edu). Using a combination of online presentations, face-to-face seminars, and field training courses, over 500 professionals have been trained as "First Detectors" of emerald ash borer, Asian longhorned beetle, and other exotic forest insects. In 2022, a new course for Mediterranean oak borer (see page 22) was developed and presented in Grants Pass. The OFPD works with the Oregon Invasive Species Council to utilize the Oregon Invasive Species Online Hotline reporting system (https://oregoninvasiveshotline.org) to submit a report and photograph of potential invasive species while in the field. The overall goal is to detect key forest invaders early in their invasion. The success of OFPD has been the result of in-person training at field courses where students can test their knowledge on signs and symptoms of specific exotic invasive species. Additionally, the in-person training offers hands-on experience with tree and insect samples and a chance to have Q&A dialogue with course instructors and participants.

Western redcedar (WRC) dieback mapping and monitoring

Results from a collaboration between Oregon and Washington that identified locations and isolated causes of WRC dieback, indicate a direct link to drought conditions: https://tinyurl.com/WRCStorymap

Forest Health education resources:

- All OSU Tree School courses: https://extension.oregonstate.edu/tree-school/tree-school-online-class-guide
- Forest insect pests: https://tinyurl.com/TreeSchool-insectpests
- Forest bees: https://tinyurl.com/TreeSchool-bees
- Forest diseases: https://tinyurl.com/TreeSchool-diseases

Forest Pollinator Projects

Over 800 species of native, wild bees occur in Oregon, many of which can be found in and along forests (Fig. 10). The Oregon Bee Project (OPB) is a pollinator protection task force established by the Oregon legislature in 2015 and includes OSU, and Oregon Departments of Agriculture, Forestry, Fisheries and Wildlife, and Transportation. OBP works to increase our understanding of, and enhance and conserve habitat for, native, wild bees and other pollinators across Oregon through research and monitoring, outreach, pesticide training, and landowner projects.

There are many ways for landowners and the general public to get more involved in efforts to understand what bees occur where, what plants they are visiting, and to enhance pollinator health and habitat:

Pollinator resources:

- Guidance on enhancing pollinator habitat in forests: https://woodlandfishandwildlife.com/ publications/ insect/forest-bee-pollinators

- Guidance on creating pollinator habitat in forests: https://extension.oregonstate.edu/collection/bees-woods

- Guidance on creating pollinator habitat in forests: https://extension.oregonstate.edu/pollinator-stew-ard#:~:text=The%20OSU%20 Pollinator%20 Steward%20Program,or%20creating%20new%20 pollinator%20habitat

- Volunteer to collect data on bee populations and plant visitation: https://www.oregonbeeproject.org/ bee-atlas

- Dedicate pollinator habitat on zoned timber land: https://www.oregonlaws.org/ors/527.678

- OSU's PolliNation podcast: https://extension.oregonstate.edu/podcast/pollination-podcast

Figure 10. Top: Pollinator foraging on native farewell-to-spring (Clarkia amoena) flowers on pollinator habitat established in the Clatop State Forest. Leafcutting bees have also cut out snippets of petals (arrow) to use as building material for their nests which are created in pithy plant stems or pre-exisiting holes in wood. Bottom (circled): Entrance holes to pollinator ground nests in the forest understory (Christine Buhl, ODF).

ABIOTIC AGENTS

Climate and weather are often primary contributors to tree health and forest conditions. Events that stress trees reduce growth and decrease their ability to defend themselves or rebound from insects, diseases, and other secondary stressors. Healthy trees can defend themselves from insects and diseases with pitch which provides chemical and mechanical defenses. Pitch contains chemicals that repel, trap, and drown insects. Pitch can also seal off wounds to prevent infestation by pathogens that cause diseases, and, further, it has anti-microbial properties and can compartmentalize and contain pathogens. When moisture levels are low, trees create less pitch and are less defended.

HEALTHY TREES = RESILIENT TREES

One of the major reoccurring stressors in Oregon forests has been ongoing drought as a result of climate change. The fact that we are experiencing changes in temperature is not unprecedented, however the rate of change is. Earth's climate patterns are affected by multiple different variables. There are natural, alternating periods of cooling and warming, and currently earth is in a warmer phase. Also El Niño (warm phase) and La Niña (cool phase) are periodic fluctuations in sea surface temperatures and overlying atmosphere that can alter climate, typically for a period of two years. 2022 was the *third* year of La Niña which, in this region, causes cooler and wetter winters. In some areas we benefited from these conditions although much of region was still in a state of drought. Our last La Niña event occurred from 2016-2018, but the last time it occurred for a span of three years ("Triple dip") was from 1998-2001.

Along with chronic conditions, we have acute events that have placed stress on trees. In 2021, we experienced a heat dome event (page 14) that caused heat stress and singed tree crowns. On April 11, 2022, a late winter snowfall (Fig. 11) contributed multiple inches of wet and heavy snow in many areas and caused power outages and tree breakage. This was the first time snow had been recorded as late as April in the Portland metro region.

Figure 11. Spring flowers doused with snow in Portland, where higher elevations received as much as 6 inches (Blake Benard).

Microclimate due to site factors also exacerbates chronic or acute climatic conditions and events. Oregon has a diversity of forest ecosystems due to variations in latitude, elevation, topography, and proximity to the ocean and mountains (rain shadow effects). All of these factors play a role in determining the impacts of altered temperature and precipitation (rain and snow) levels. Additionally, soil and ground cover type, local water use, and watershed dynamics can place different pressures on water storage capacities. Tree stocking levels influence the competition among trees for the availability of water resources. Some tree species have strategies to tolerate drought better than others, however trees can tolerate drought for only so long and repeated droughts compound this stress.

Changing climactic conditions are not just about record highs and lows. Their impacts are felt even more strongly due to their timing, duration, frequency, and rate of change. For example,

1. Droughts during active growing periods (spring) can be more damaging than if they occur during dormant periods (winter)
2. Short droughts can be tolerated by some species that have evolved the ability to reduce water loss through leaves. As this limits photosynthesis this strategy does not work during prolonged droughts
3. If there are back to back years of drought and trees don't get a reprieve to rebuild damaged tissues, they may never catch up even if a drought period is punctuated by adequate precipitation, and 4) sudden changes in heat or precipitation can shock trees even if changes are moderate.

Drought

2022 tied 2014 as the 8th warmest year, and was 0.7 °F warmer with 1.11 inches less precipitation than average from 1896-2022. Some months, such as October 2021, were cooler and wetter than average for most of the state but November returned to warmer and drier conditions than average. Snowpack water equivalent at the start of December was <50% of the 1991-2020 median throughout the Cascades and all other mountain ranges in Oregon. Conditions improved in the second half of the month and in January snowpack water equivalent, relative to the 1991-2020 median, increased to 140-200% of the average from central-northern Cascades and >500% in some areas of the southern Cascades. Despite this influx of snow, peak snowpack in Klamath was reached in January, and was only 67% of the historic average for peak snowpack levels, then quickly declined.

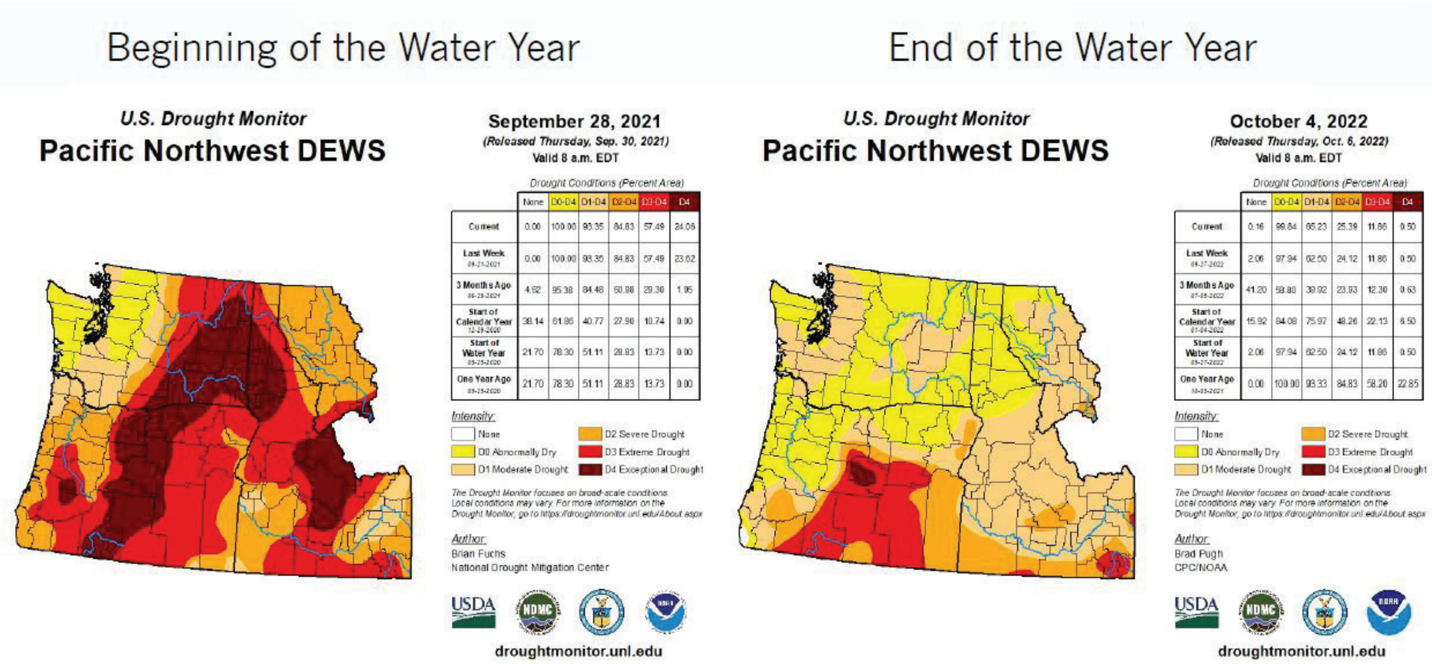


Figure 12. Average drought ratings for the Pacific Northwest from the beginning to the end of the previous "water year" (Sept 2021 to October 2022) relative to the average normal based on 115 years spanning from 1895 to 2010 (Western Regional Climate Center).

Spring conditions were unseasonably cool and April through June conditions were the 17th coldest and 2nd wettest on record relative to the 1991-2020 average. Despite cooler temperatures, precipitation was still lacking and from March-June drought was declared for Douglas and Jackson counties as well as all counties east of the Cascades. The period from July-September was the warmest and 7th driest relative to 1991-2020 averages. In summary, during the water year (September 30, 2021 to October 1, 2022) Oregon experienced above normal temperatures and below normal precipitation. Predictions from the National Weather Service Climate Prediction Center indicate that Oregon will experience a wetter and cooler spring and a warmer than normal summer in 2023.

2021 Heat wave / Heat dome continuing impacts

In 2021, Oregon experienced an anomaly termed the "heat dome" that resulted in a multi-day record heat wave across the state. Temperatures in Portland reached 108°F on June 26th, then 112°F and 116°F over the next two days. The greatest intensity of damage occurred on the youngest (branch tips) and most exposed (south- and west-facing aspects, forest edges, along pavement) tree tissues. Regions unaccustomed to high temperatures, such as the coast, were also heavily affected. In 2022, damage from this event was still visible during aerial surveys. Coniferous trees that experienced foliage scorch in 2021 (Fig. 13) either dropped scorched needles or they turned from red to brown and looked dingy from the air during 2022 surveys. Despite this damage, many trees still produced viable buds on at least part of their crowns and flushed needles as usual. Although we did not observe widespread mortality in 2022 from the 2021event, it is another layer of stress for our droughted trees.

Figure 13. 2021 scorched foliage (Danny DePinte, USFS).

Climate change and drought resources:

- Oregon Water Resources Department's monthly drought summary email: https://tinyurl.com/drought-report
- Oregon Climate Change Assessment (published every two years): https://blogs.oregonstate.edu/occri/ oregon-climate-assessments
- Drought impacts on forests and pests: https://youtu.be/wHZ1G5wH4r8
- National Drought Mitigation Center drought symptoms reporting survey: https://go.unl.edu/cmor_drought
- University of Washington Climate Impact Group Earthlab, Climate projection tool: https://cig.uw.edu/resources/analysis-tools/pacific-northwest-climate-projection-tool

Figure 14. Symptoms of drought (left to right): flagging (dying branches), thinning crown and stress cones, asymmetrical crown (from uneven foliage then twig and branch loss), and topkill (note the progression of mortality) (Christine Buhl, ODF).

How are trees impacted by drought?

Symptoms of drought stress (Fig. 14) often progress slowly relative to mortality from bark beetles which can occur within the span of a year. Symptoms of drought are direct manifestations of damage to water collection and translocation tissues. Water is collected by roots and transported throughout the tree via a network of tubes (vascular tissues) then released from pores in leaves (stomata) into the atmosphere (Fig. 15).

Dry or windy conditions can increase water loss from leaves. Drought stress can strain or collapse vascular tissues or cause dieback of roots. It can take many years for trees to rebuild these tissues during which time they have fewer tissues to actively absorb water for the tree. Trees can tolerate drought for a short period by closing stomata to reduce water loss to the atmosphere, but this halts photosynthesis which starves the tree. Trees may also prematurely drop leaves to reduce the amount of tissues that both consume and release moisture, but this also reduces photosynthesis. Interruptions to photosynthesis reduce both growth and resources allocated toward defense which makes trees less resilient to other stressors such as insects, diseases, mechanical damage, etc. For most trees, there are no long-term drought tolerance solutions and prolonged or repeated droughts often result in mortality, sometimes years later. Although drought conditions did somewhat improve in some areas of Oregon, it takes more than one or two years of more moisture for trees to recover. Even if moisture availability increases, trees may be too damaged from prior drought stress for roots and vascular tissues to function.

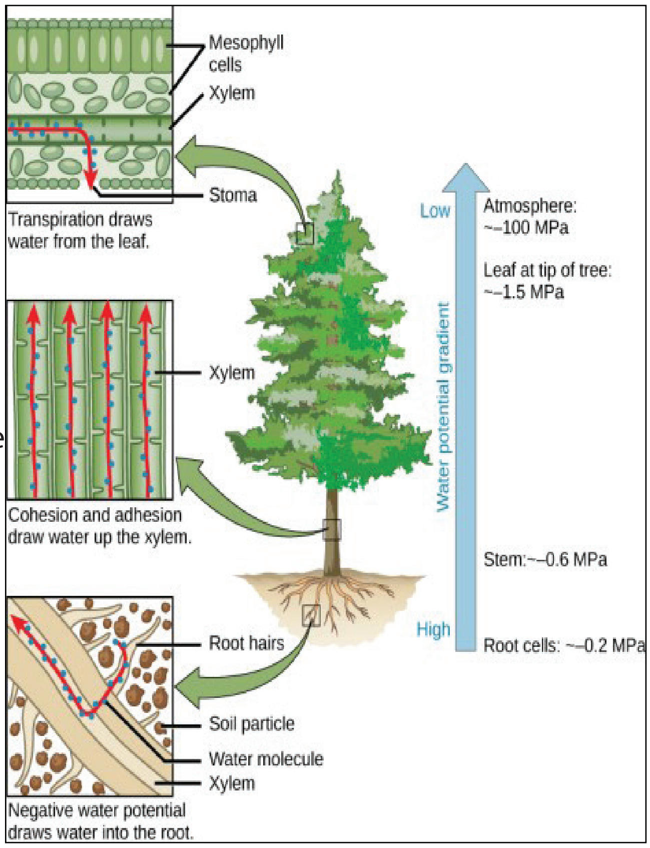


Figure 15. Trees absorb moisture via roots in the soil and translocate it throughout the canopy via a network of tubes (vascular tissues, xylem). When droughts occur, roots die back and these tubes collapse so that even if precipitation increases they may too damaged to access it. Water loss occurs through "breathing" pores in leaves (stomata) and can be hastened via wind and heat. Resistance and tolerance to droughts varies among tree species due to variations in physiology and responses. More extensive root systems and periodic closure of stomata to reduce water loss can help trees avoid drought stress - but only for so long (Model courtesy of OpenStax and used under Creative Commons license).

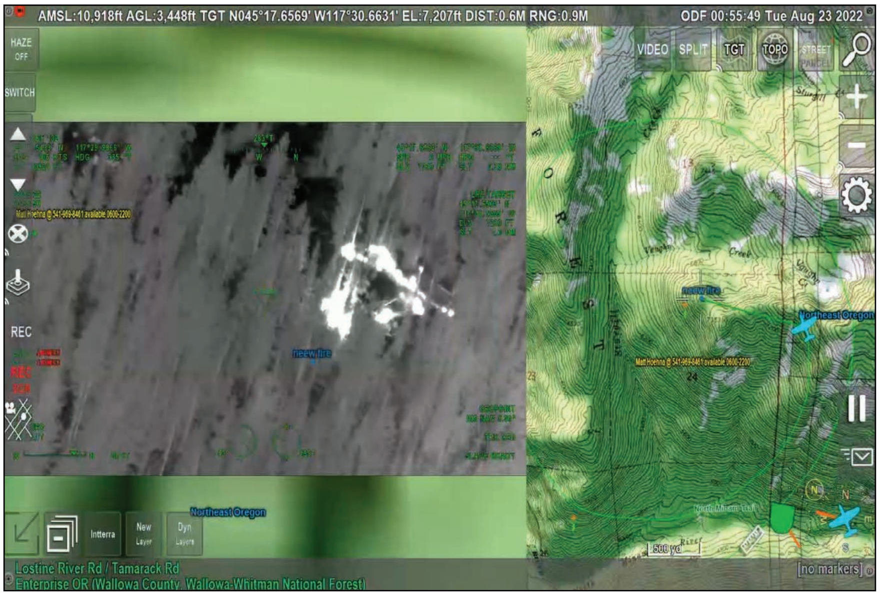
Overview of drought impacts on trees: https://sflonews.wordpress.com/2021/08/12/drought-and-tree-mortality-in-washingtons-conifers/

Ensuring that trees have the best chance for success results from a healthy start and promoting ongoing resiliency:

1. Plant: Native species, seed sources local to your region, and species adapted to the various conditions and micro-climates (soils, aspect, sun or wind exposure, etc.) at your site. Pay attention to which species are doing well where. Do not continue to replant with species that are struggling to survive or don't naturally regenerate. Stay within your seed zone as much as possible. It may be okay to go outside of seed zones slightly if necessary (east-west 1-2 zones; north-south 1 zone; from down slope (but not up)). Seedlot selection tool: https://www.climatehubs.usda.gov/hubs/northwest/topic/seedlot-selection-tool. Establish seedlings with care to give them the best start to a long and productive life.
2. Maintain: Plan for stand density that can tolerate climate change and extreme weather events. Discuss spacing with ODF, OSU or other forestry consultants (page 1) to account for a warming climate, inconsistent precipitation, and realistic pre-commercial thinning and harvest timelines. Reduce competition from other competing plants especially grasses and invasive species. Do not fertilize during droughts because increased growth increases moisture requirements.
3. Prevent and control: Manage fuels. Reducing unnatural wildfire risk prevents fire-damaged and beetle-susceptible trees. Be aware of the major insects and diseases that occur in your tree species and in your region (pgs. 36-37). Follow management guidance. Remove weak, injured or extremely stressed trees.

Wildfire

The wildfire season started off slowly but late season fires in Oregon and assistance provided to other states such as Alaska, Texas, and Washington kept crews busy (Fig. 17). In 2022, approximately 445,000 acres were damaged by wildfire, which was 34% lower than acres damaged in 2021 and 27% lower than the 10-year average (Fig. 18). The largest fires were caused by lightning: Double Creek near Enterprise totaled 170k acres and Cedar Creek near Oakridge totaled 130k acres (Fig. 18). 96% of ODF wildfires were kept at 10 acres or less, in large part due to early detection from heat detection monitoring from Forward Looking InfraRed (FLIR) cameras affixed to the ODF survey plane (Fig. 16).



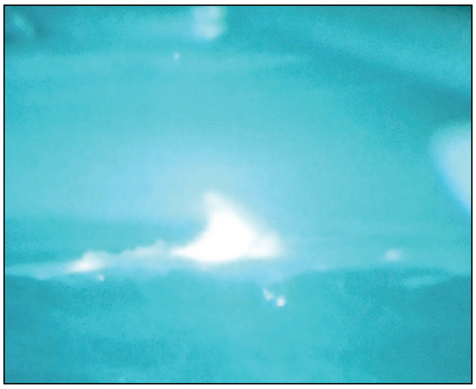


Figure 16. Clockwise from top: 1) Split-screen Augmented Reality System (ARS) screenshot showing the infrared image (L side) of a newly detected fire start and its corresponding position on the map, 2) Fire as seen through night vision goggles, 3) Steel & plexiglass "cage" that houses the FLIR unit when it is retracted into the cabin of the ODF plane. The observer sits next to this unit, 4) ODF Partenavia plane that is affixed with FLIR camera (Cole Lindsay, ODF).

Wildfire resources:

- Post-fire mortality estimation guide: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd1013251.pdf
- ODF fuels reduction cost share program: https://tinyurl.com/ODFcostshare
- ODF "Help After Wildfire": https://www.oregon.gov/odf/fire/Pages/afterafire.aspx
- OSU Extension Fire Program: https://extension.oregonstate.edu/fire-program
- OSU Extension wildfire webinars: https://extension.oregonstate.edu/fire-program/online-webinar-guide
- Oregon Statewide Wildfire Response & Recovery: https://wildfire.oregon.gov
- Make your home Firewise: https://www.nfpa.org/Public-Education/Fire-causes-and-risks/Wildfire/ Firewise-USA
- ODF KOG Reduce risk of wildfire starts: https://keeporegongreen.org

Figure 17. Scenes from wildfire. Left: Fishhawk Loop (Dan Goody and Matt Catton, ODF), Right: Rum Creek (Marcus Kauffman, ODF).

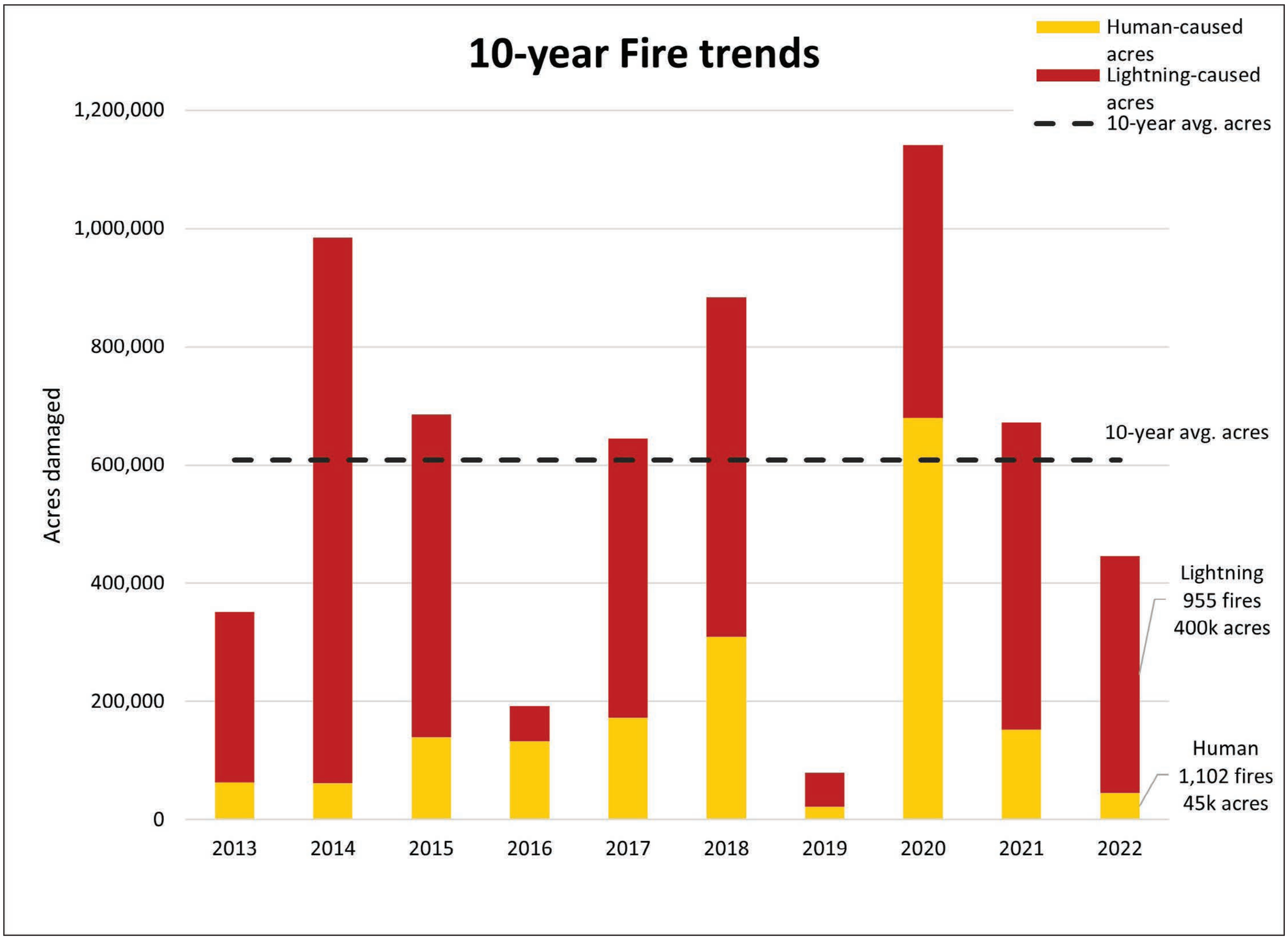


Figure 18. 10-year wildfire trends, across all ownerships and all protection teams (USFS, BLM, ODF, tribal, etc.).

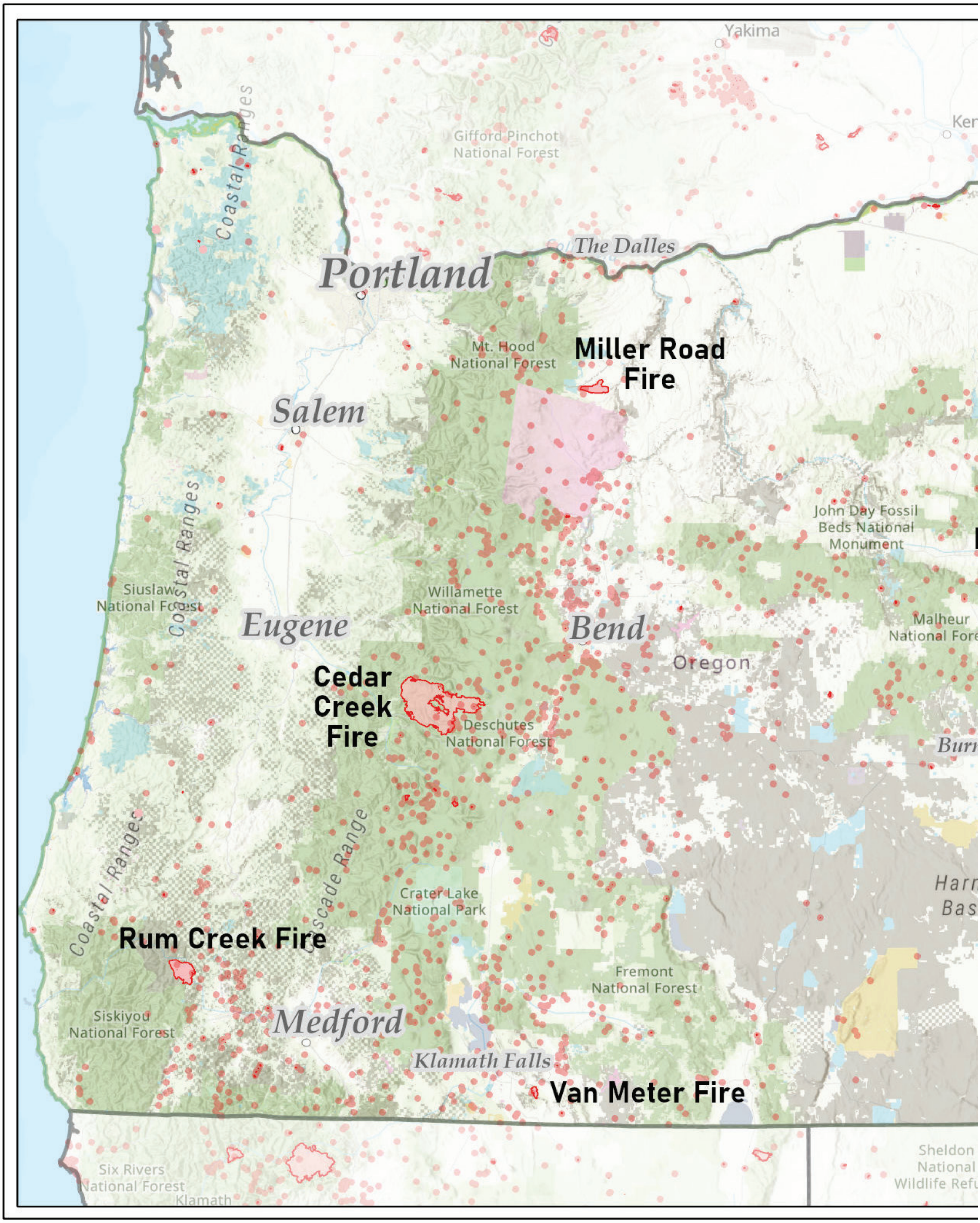
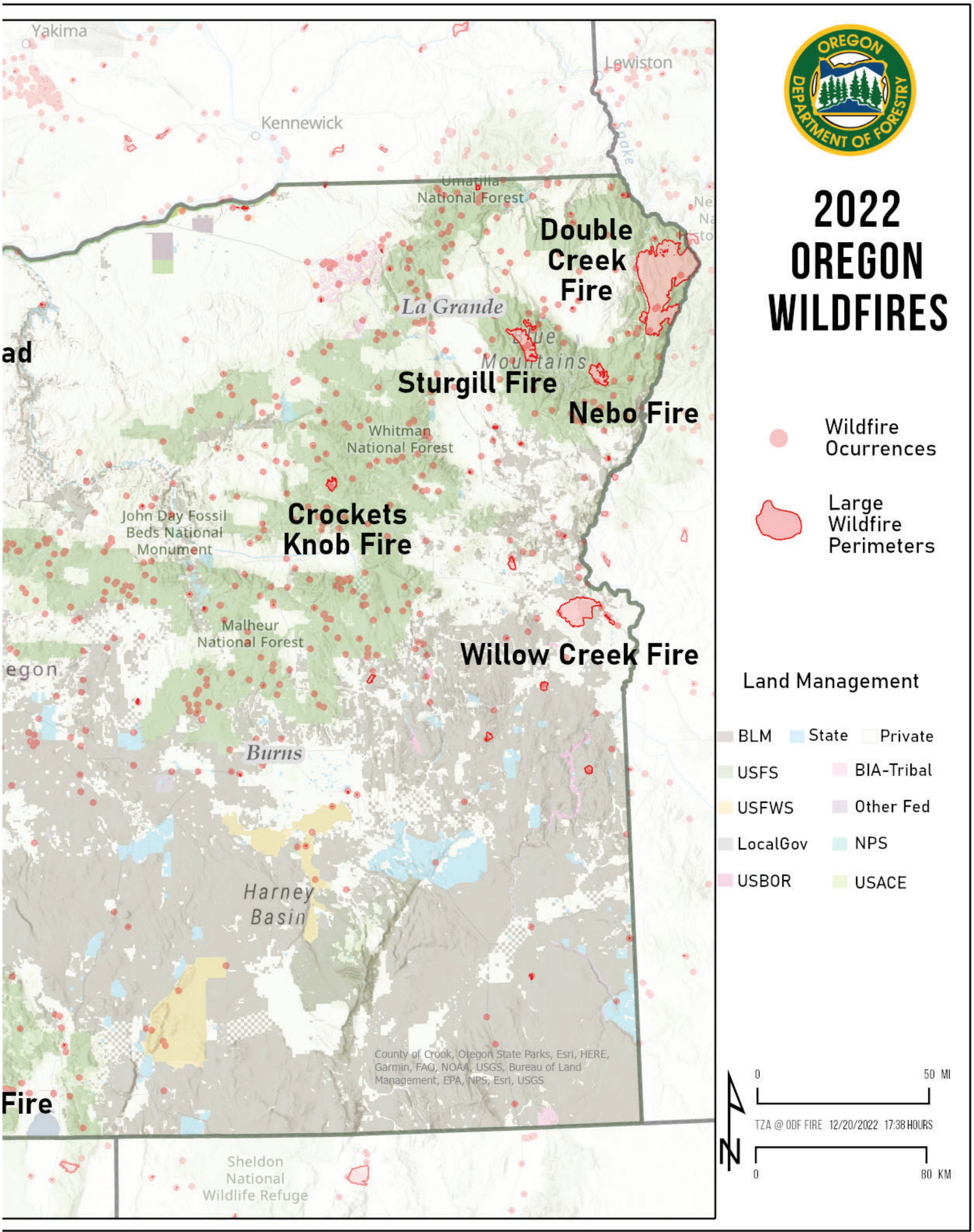


Figure 19. Map of statewide wildfires in 2022 (Teresa "TzA" Alcock, ODF).



2022 OREGON WILDFIRES
Double Creek Fire
Sturgill Fire
Nebo Fire
Crockets Knob Fire
Willow Creek Fire
Fire
Yakima
Kennewick
Lewiston
Umatilla National Forest
La Grande
Blue Mountains
Whitman National Forest
John Day Fossil Beds National Monument
Malheur National Forest
Burns
Harney Basin
Sheldon National Wildlife Refuge
Wildfire Ocurrences
Large Wildfire Perimeters
Land Management
BLM
State
Private
USFS
BIA-Tribal
USFWS
Other Fed
LocalGov
NPS
USBOR
USACE
County of Crook, Oregon State Parks, Esri, HERE, Garmin, FAO, NOAA, USGS, Bureau of Land Management, EPA, NPS, Esri, USGS
0
50 MI
TZA @ ODF FIRE 12/20/2022 17:38 HOURS
0
80 KM
N

Healthy trees are defended trees. Tree defenses include mechanical and chemical defenses in foliage and wood that prevent infestation, mitigate damage, or kill insects. For trees to produce these defenses they must have their growth requirements met, sparing additional resources that producing defenses requires. Droughts, in particular, impact defenses because trees require moisture for tree pitch, their main defense, which acts as a mechanical barrier that traps insects and also contains chemicals that are repellent or toxic to insects and the microbes and fungal pathogens that insects may vector.

ODF Insect pest guide: https://www.oregon.gov/odf/Documents/forestbenefits/InsectPestDiagnosis.pdf
ODF forest pest fact sheets and videos: http://tinyurl.com/ODF-ForestHealth

Beetles

In recent years the majority of tree damage and mortality has been detected in the tree genus *Abies*. also known as "true fir" species. The primary causes include chronic hot droughts, root disease, balsam woolly adelgid and subsequent attack by fir engraver beetles (*Scolytus ventralis*). Many of these sites are becoming marginal for tree growth due to climate change and the spread of balsam woolly adelgid. In 2022, we observed historic levels of true fir mortality across much of its range although mortality was greatest in SW and Central Oregon, particularly in drier areas. It should be noted that fir is more abundant in some areas due to encroachment following fire exclusion. Much of this damage is and has been historically recorded as fir engraver damage. Fir engraver bark beetle does not typically have the ability to kill healthy trees, but can kill stressed trees, and the most common underlying stress (and primary cause of tree mortality) in true firs is drought and/or root disease.

Other beetles that typically kill stressed trees include Douglas-fir beetle (DFB, *Dendroctonus pseudotsugae*) and flatheaded fir borer (FFB, *Phaenops drummondi* prev. *Melanophila*) in Douglas-fir, and Ips (*Ips* spp.), western pine beetle (*Dendroctonus brevicomis*) and mountain pine beetle (*Dendroctonus ponderosae*) in pine. As with fir engraver, these beetles are native and widely present on the landscape at endemic levels. However, if there's a large availability of stressed trees, beetle populations can build into unnaturally large levels that may spill over into healthy trees and overcome their defenses. In recent history, ongoing hot drought has predisposed trees to infestation and mortality from these beetles. For example, in recent years southwest Oregon has perhaps been hit the hardest by intense and frequent droughts. Fallout has included large

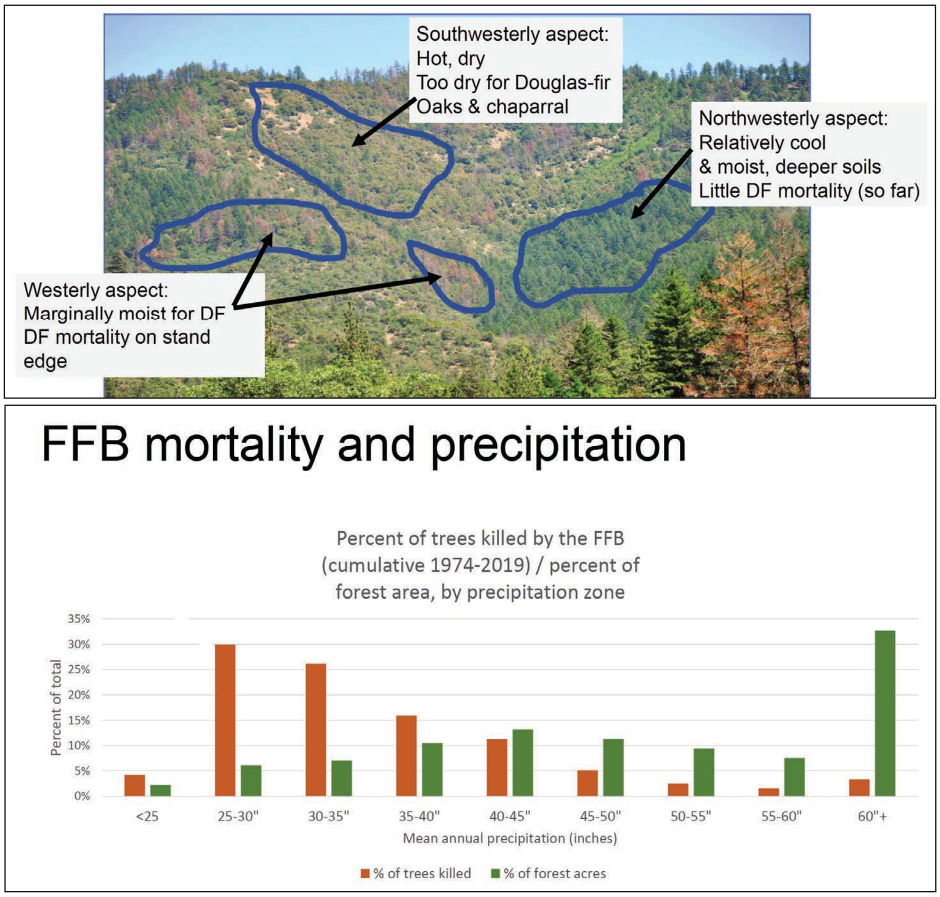


Figure 20. Top: areas on the landscape that have microclimates or conditions that stress trees, making them more susceptible to FFB. (Ellen Goheen, USFS & Max Bennett, OSU). Bottom: annual precipitation and % acres with tree mortality identified in aerial surveys as flatheaded fir borer (orange) and percent forest cover in these areas (green) (Max Bennet, OSU). Note, trees are marked in surveys as "flatheaded fir borer" are more often a complex of drought, FFB and/or DFB.

swaths of Douglas-fir mortality particularly on harsh sites such south-facing slopes, forest edges, dry low-elevation areas, and areas with shallow soils (Fig. 20). These trees suffer from the primary stress of decreased precipitation and secondary impacts of infestation by opportunistic FFB and DFB (Fig. 20). In some of these areas, fire exclusion has allowed Douglas-fir encroachment or increased abundance at less suitable, droughtier sites.

Bark beetle management: Other landscape-level stressors such as storms and wildfires also damage trees and increase their susceptibility to pests. It is important to identify and target the primary source of tree stress for management. Focusing on controlling beetles alone provides only a short-term solution or more likely doesn't help at all. The primary methods of management or mitigation of these pests is preventative because control measures are far too expensive or not effective at the stand level. To reduce pest susceptibility, management strategies should target enhancement of tree resiliency to drought and wildfire by reducing stand density and fuels buildup. Management of other high-stress situations that attract pests should also be addressed:

- Root disease pockets should be managed by switching to alternate species, buffer cuts, increased sanitation to prevent spread, or more targeted strategies depending on the specific pathogen
- Fresh pine slash should be treated to prevent Ips beetle outbreaks: https://www.oregon.gov/odf/Documents/forestbenefits/Slashmanagement.pdf
- MCH anti-aggregant pheromone should be applied right before the April following storm damage or wildfire to prevent DFB outbreaks: https://www.oregon.gov/odf/Documents/forestbenefits/MCH_2016.pdf

Cost share funds are available for bark beetle prevention and mitigation treatments such as thinning, pine slash management, and anti-aggregation pheromones: https://tinyurl.com/ODFcostshare.

Figure 21. Left to right: bark beetle infestation signs and symptoms include frass, pitch streams, pitch tubes, and exit holes (Christine Buhl, ODF).

It is important to identify if you are dealing with bark beetles which can kill trees, versus woodboring beetles that just cause defect, and if bark beetles are still present. Bark beetles infest only living trees and move through their life cycles typically within a year or less. It is important to recognize the signs and symptoms (Fig. 21) of infestations to employ mitigation techniques in a timely manner and reduce population outbreaks in areas of active beetle infestation. Bark beetles can identify the "smell" of a tree species and determine if it's under stress. They can also communicate chemically with their species to attack en masse and regulate population numbers. All of which make them effective at opportunistically attacking stressed trees. When they burrow into a tree they kick out brown (not white) sawdust or "frass" because they are chewing through bark and only etching the surface of wood itself. If the tree has enough moisture to produce pitch, you may see small pitch globs/tubes (pine), thin pitch streams (Douglas-fir) or pitch droplets (true fir) on the outer bark. If beetles are not drowned by pitch they will create feeding galleries under the bark that have distinct, species-specific patterns. Bark beetles kill trees by girdling vascular tissues with their galleries and clogging these tissues with vectored fungi. When adult offspring chew their way out of trees they create many tiny, perfectly round exit holes about the size of the tip of a ballpoint pen. Some woodborers (e.g., ambrosia beetles) make similarly-sized exit holes however those holes continue through the bark and into the wood. By the time a tree's foliage has turned red, bark beetles are often already gone.

Woodboring beetles (e.g., ambrosia beetles, longhorned beetles/roundheaded borers and jewel beetles/flatheaded borers) can be confused with bark beetles, although most woodborers don't typically kill trees but can cause defect by tunneling into wood, and ambrosia beetles vector fungal stains. Woodborers commonly attack severely stressed trees such as those injured by rot or wildfire (https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd1013251.pdf). Woodboring beetles kick out white frass because they tunnel into wood. Other signs include extensive tunnels, and round or oval exit holes that may be as wide as a pencil eraser.

NEW EXOTIC PEST DETECTION:
Mediterranean oak borer (MOB, *Xyleborus monographus*) is an exotic ambrosia beetle that is a recent arrival to North America. These tiny beetles carry fungi in specialized pits near their mouths, which they use to inoculate tunnels in sapwood of hardwood hosts. The fungi that grow in the tunnels are then fed on by developing larvae (Fig. 22). MOB vectors several fungal species; one in particular, *Raffaela montetyii*, is pathogenic on numerous oak species, including Oregon white oak (*Quercus garryana*), in both its native range of Europe and its introduced range in North America.

Figure 22. MOB galleries in wood (left) from adult MOB beetle (center) whose damage causes canopy dieback and mortality in oak trees (right) (University of California Riverside).

In 2019, large populations of MOB were observed killing valley oak (*Quercus lobata*) in Napa and Sonoma counties of Central California. The insect has probably been present in California since the early 2010s. While no reports of oak mortality have been reported in Oregon, the insect has been detected in increasing numbers in traps. In 2018 a single MOB was captured in an ODF trap in Multnomah County. In 2021, a second MOB individual was captured in an ODA trap in Marion County. In 2022, the ODF Forest Health unit assisted ODA in a surveillance program, and 21 MOB specimens were captured in traps at seven sites across four counties: Marion, Clackamas, Washington and Multnomah.

In May of 2022, the ODF Forest Health Unit, in conjunction with USFS and OSU Forestry Extension, led an early detection training for natural resource professionals at Rogue Community College Redwood Campus in Grants Pass. Participants learned the signs and symptoms of MOB and how to report suspect trees.

NEW EXOTIC PEST DETECTION: Emerald ash borer (EAB, *Agrilus planipennis*)

On June 30, 2022, a suspected emerald ash borer infestation at Joseph Gale Elementary School in Forest Grove was reported to ODF. ODF Forest Health staff visited the site on the same day and observed 16 symptomatic ash trees and collected insect samples which were confirmed to be EAB. EAB adults were abundant and observed feeding on foliage of the affected trees. On July 1, ODF Forest Health staff collected foliage samples from four symptomatic trees at the site, placed four EAB traps on the school premises, and collected additional adult specimens. Additional infested ash trees were discovered on July 1 in the neighborhood surrounding the school, including one native Oregon ash (*Fraxinus latifolia*). On July 2 an arborist removed and chipped the 16 infested trees. Within a 24-hour period, over 300 adult beetles were captured in the EAB traps placed at the school. Based on the progression of tree decline and signs of the insects in the tree, ODF and other agencies concluded that the infestation had been present at the site for at least three years.

Figure 23. Left: Common symptoms of EAB infestation include canopy thinning and topkill, epicormic shoots from the trunk, and bark splits (not shown) (Leah Bauer, USFS). Right: A key exterior sign of EAB infestation is 1/8 inch, D-shaped exit holes (Christine Buhl, ODF). EAB spends only a very small portion of its life outside of a tree and is not often seen outside of the summer flight period. Larvae and their serpentine galleries can be found under the bark most of the year. Very few non-pest insects similarly affect ash trees.

On July 5, the Oregon interagency emergency response plan for EAB, which was first published in 2018, was activated. ODA became the lead agency in the response effort and formed an interagency task force comprised of over 40 local, state, federal agencies, as well as non-profit organizations and academic institutions. Guided by a steering committee, the EAB Task Force met once a month starting in August. The agencies organized and coordinated work through seven subcommittees: Survey and Monitoring, Wood Waste and Wood Utilization, Communications, Integrated Pest Management, Training, Research, and Funding.

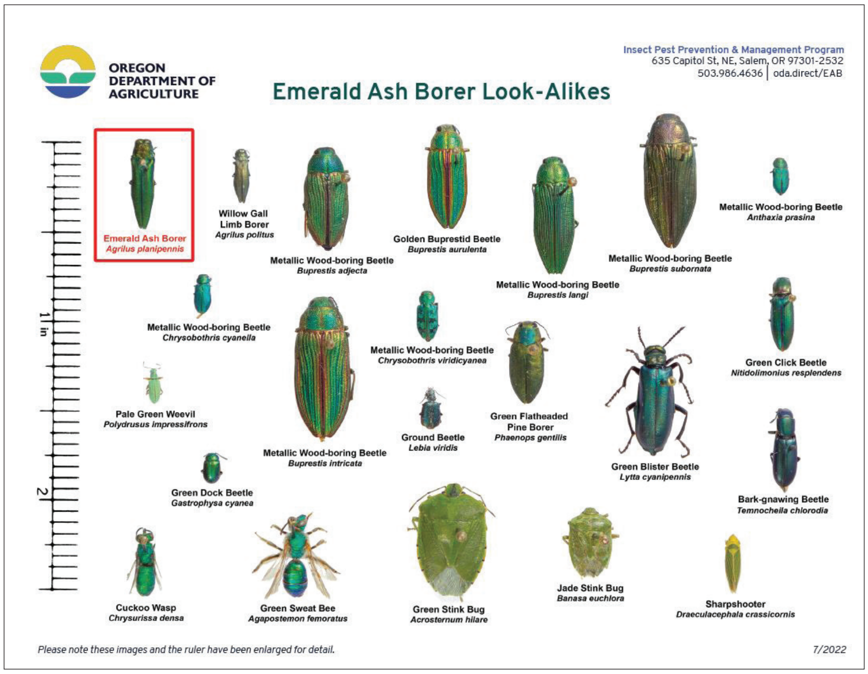
Under the Survey and Monitoring subcommittee, ODA developed an interagency tree survey where trained professionals could inspect individual ash trees, note the presence/absence of EAB signs and symptoms (Fig. 23)and upload the recorded data to a real-time public dashboard. From the initial detection on June 30 to the end of the year, over 3,000 ash trees in Washington County and other locations in Oregon were inspected for EAB by numerous local, state and federal agencies. As of January 2022, over 50 EAB-infested trees have been detected in this interagency survey. The USDA Animal Plant Health Inspection Service (USDA APHIS) and ODF placed purple panel traps in Washington county. One ODF trap in Forest Grove was positive for EAB while all others were negative. On December 20, ODA adopted a temporary 180-day quarantine, limiting the movement of ash, olive and white fringe tree material out of Washington County.

Several other efforts to preserve ash on our landscape are in progress. ODF and USFS developed a seed-collecting project for Oregon ash that began prior to this first EAB detection. This project aims to collect ash seeds from populations in Oregon before EAB causes widespread mortality. Seeds are stored in freezers for genetic conservation (USDA Seed Lab, Fort Collins) and resistance research (USFS Dorena Genetic Resource Center and USDA Agricultural Research Service, Ames, IA). In 2022, approximately 450,000 seeds were collected from 134 trees across western and southern Oregon. These seeds were added to 2019 collections (350,000 seeds from 100 trees). In April, ODF Forest Health staff assisted a team of researchers from Penn State University to collect foliage samples of Oregon ash from over 200 individual trees across the state. The research will focus on mapping the genome as well as documenting the population genetics of the tree species – a first for Oregon ash.

Figure 24. Ash tree seeds (samaras) (Christine Buhl, ODF).

EAB resources:

- Report suspected infestations to Oregon Invasives Online Hotline: https://oregoninvasiveshotline.org/ *(Review what EAB and ash trees look like and include location and image in report, Fig. 25)*
- EAB ID and look-alikes: https://www.oregon.gov/oda/programs/IPPM/SurveyTreatment/Documents/EABLookAlikes.pdf
- Ash tree ID: https://extension.oregonstate.edu/gallery/recognizing-ash-trees-oregon-washington-northern-california
- EAB fact sheet: https://tinyurl.com/odf-eab
- Map of monitoring locations and infestations: https://geo.maps.arcgis.com/apps/dashboards/e6ff6b60f63b4c489cdee61315a85535
- Oregon's EAB Readiness and Response Plan: https://www.OregonEAB.com
- http://www.oregon.gov/ODF/ForestBenefits/Pages/ForestHealth.aspx
- https://extension.oregonstate.edu/collection/emerald-ash-borer-resources
- https://www.oregoninvasivespeciescouncil.org/eab



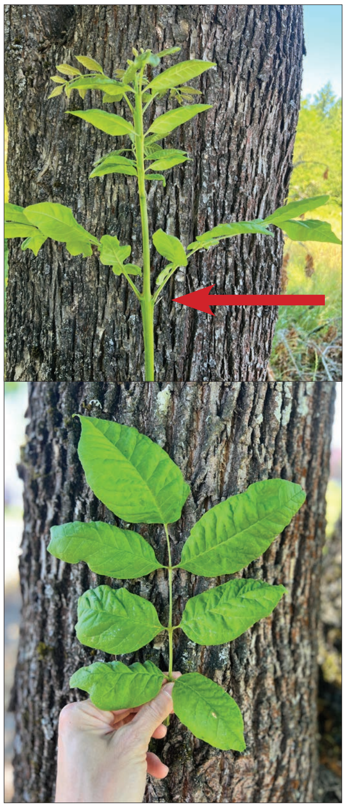


Figure 25. Left: EAB relative to look-alikes found in Oregon (ODA). Right: Features used to identify ash include: (top) opposite branching (branches mirror each other in their position on the main stem), (bottom) compound leaves (5-9 leaflets attached to one stem), lattice-like bark as trees mature, and single-winged seeds (Fig. 24) (Christine Buhl, ODF).

EAB history in the United States

Since 2001, EAB has become the most destructive invasive forest insect pest in the United States. It attacks and feeds on ash (and some other relatives in the Oleaceae family such as fringree and olive – although at a lesser degree). Since its introduction into the Great Lakes Region in the 1990s, it has spread to over 35 states, killing over 100 million ash trees, threatening extinction of a number of eastern U.S. ash species. Until the discovery in Oregon, the furthest known western extent of EAB was Boulder, Colorado. EAB spreads long distances through firewood and ash nursery stock. In 2021, APHIS dropped the federal quarantine for interstate movement of EAB and EAB-infested material.

There is a significant risk of emerald ash borer to Oregon's riparian forests. In Oregon, a native and susceptible ash, grows widely across the western part of the state in riparian areas, in habitats occupied by threatened and endangered species and other rare species. Rapid mortality of this native tree caused by EAB is expected to cause changes in riparian plant communities, increase stream temperatures, and alter food webs. Oregon ash is also grown by some tree farmers as a specialty niche crop for forest products or for conservation and restoration efforts. Pockets of ash often occur in areas unsuitable for our other native tree species and the loss of these stands would reduce the ecological and aesthetic value of these areas. If this current infestation follows patterns seen in eastern states, EAB will likely decimate this small but important market, as well as wild ash stands within approximately 10 years. Moreover, rapid ash mortality in Oregon's cities and urban forests will cause significant economic strain on local governments and property owners.

In Oregon, surveys for EAB have occurred sporadically when federal funding was available starting in 2005. ODF alone placed nearly 1,000 traps for EAB during 2013-2015. No EAB were detected in Oregon until June 30, 2022, in Forest Grove.

In 2015, OSU Forestry Extension, ODF, ODA, USFS, and APHIS launched the Oregon Forest Pest Detector program (https://extension.oregonstate.edu/ofpd) to train natural resource professionals on how to recognize and report suspected EAB. To date, over 500 natural resource professionals have taken the training.

Figure 26. Ash is an essential component of most riparian areas in Oregon and a common street tree. Willamette Valley agricultural fields and savannas are also dotted with islands of pure Oregon ash, Fraxinus latifolia (top and right; Wyatt Williams, ODF). If ash is lost at these sites they may not be able to support other tree species as Oregon ash in particular is tolerant of the alternating dry and wet soil conditions present at these sites. The loss of trees in these areas will have negative impacts on moisture retention, water temperatures, nutrient cycling, and wildlife habitat.

Defoliators

At the end of summer and into the fall, white oaks in the Willamette Valley started showing noticeable damage from oak lace bugs (*Corythucha arcuata,* Fig. 27) (https://oregonforestry.wpengine.com/2022/11/08/browning-leaves-on-oregon-white-oak-may-be-due-to-damage-from-the-invasive-oak-lace-bug). Oak leaves were mottled yellow to brown and the undersides of leaves contained tiny black droplets of excrement, cast skins, and oak lace bug adults and nymphs. These insects, which are native to other parts of the U.S., were first identified in Oregon in 2015 and have become established in Oregon. This recent uptick in populations may have resulted from favorable conditions for the insect such as mild winters, declines in natural enemy populations, or an abundance of a oaks with reduced defenses. It is common to see brown patches of leaves throughout oak crowns due to a myriad of foliage-attacking insects or damage from squirrels peeling branches in search of grubs. All of these insects, including oak lace bug, are mainly causing superficial damage because they do not harm buds, and because white oaks are deciduous and lose their leaves each year to flush new leaves as normal the following year.

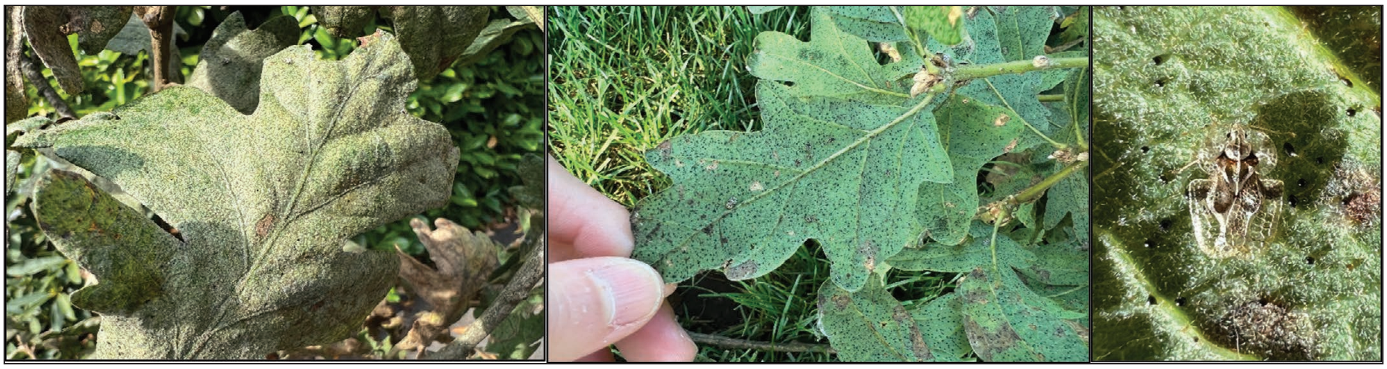


Figure 27. Oak lace bug signs and symptoms include: (left) yellow-stippled leaf, (middle) adults and black excrement droplets, (right) 1/8" transparent adult (Christine Buhl, ODF).

The major conifer defoliators that caused damage in 2022 include balsam woolly adelgid (BWA, *Adelges piceae*) in true fir, Douglas-fir tussock moth (*Orgyia pseudotsugata*) in Douglas-fir and true fir, and pandora moth (*Coloradia pandora*) and sawflies (*Neodiprion* spp.) in pine. These defoliators are periodic except for BWA which is a chronic pest. BWA is native to Europe but has been long-established in Oregon, particularly in higher elevation trees where control or sanitation is difficult (Fig. 28). True firs tend to hold onto their dead, dry foliage for longer than other conifers therefore extensive mortality from this insect can also contribute to increased wildfire risk. Other than BWA, outbreaks from all of the other defoliators are in decline or on the verge of collapse in most areas. DFTM outbreak initiation was staggered and so some areas are still experiencing some high trap catches and noticeable defoliation.

Figure 28. True fir trees damaged and killed by BWA (ODF).

Defoliation that caused lacey-looking leaves in alder from alder flea beetle (*Macrohaltica ambiens* prev. *Altica ambiens*) was also observed in some areas. These insects do not harm buds and, as these trees are deciduous, they will drop leaves at the end of the year and reflush new leaves as normal the next spring.

Non-established exotic pest: Spongy moth (prev. European gypsy moth, *Lymantria dispar dispar*) is the European subspecies and is established in eastern parts of the U.S. and routinely found in Oregon. Flighted spongy moth is the Asian subspecies (prev. Asian gypsy moth, *Lymantria dispar asiatica*), which is not established in the U.S. but is occasionally detected in western states from overseas imports. Both subspecies feed on several hundred species of trees and shrubs and flighted spongy moth can also feed and develop on conifers. Spongy moth females are flightless however flighted spongy moth females can fly (up to 50 miles). Since the 1970s Oregon has deployed monitoring traps across the state for early detection and swift eradication using insecticide treatments. In the last several years, state funding for this large trapping program has been generated from the Oregon Lottery. In 2022, seven spongy moths were found in traps (Clatsop, Columbia, Washington and Benton counties) and delimitation trapping for potential eradication efforts will take place next year. Follow-up delimitation of a flighted spongy moth trap catch from 2020 on Sauvie Island, OR yielded no additional individuals in 2021 or 2022. Despite frequent introductions into the state, to date, infestation of each subspecies found in Oregon has been successfully eradicated.

Figure 29. WSDA staff in sting-proof suits destroying a NGH nest (WSDA).

Other insects

Non-established exotic pest: Northern giant hornet (*Vespa mandarinia,* NGH), previously called Asian giant hornet aka "murder hornet", is an exotic species from east Asia. It is the largest hornet in the world and can reach up to 2 inches in length. It often nests in forested areas and feeds on tree sap. It also attacks honeybees, which are often kept in forested areas. There is concern around this insect establishing due to its aggression toward honey bees and potential human health risk due to their large nests and large venom load.

NGH was first reported in northern Washington in 2019, and has been found in Canada in previous years. Washington State Department of Agriculture (WSDA) has employed intensive eradication techniques that include trapping, and following hornets back to their nests which are then destroyed by staff wearing sting-proof suits (Fig. 29). NGH has been observed attacking paper wasp nests which are being targeted as sentinel monitoring sources. In 2022, no hornets or nests were found. The hornet has never been found in Oregon. This insect is often mistaken for many other species that are found in Oregon such as cicada killers (Sphecidae), sawflies, bald-faced hornets, and yellow jackets (Fig. 30). Features that distinguish NGH are its large head and overall size. ODA trapped for hornets in 2021 and 2022 with plans to trap again in 2023. In 2022 ODA deployed 120 hornet traps across 13 counties in Oregon, with the majority placed in Multnomah County. To date, no hornets have been found in Oregon. If you think you have found NGH please report it to the Oregon Department of Agriculture using their online reporting system: https://oda.fyi/HornetReport. They can also be contacted at plant-entomologists@oda.oregon.gov or 503-986-4636

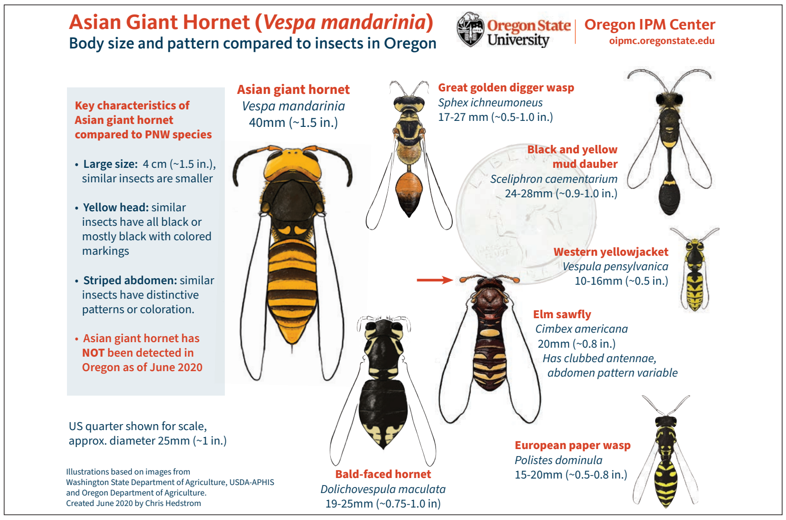


Figure 30. NGH relative to look-alikes (Oregon State University publication EM 9297).

NGH resources:

- Online identification form: https://oda.direct/InsectID
- https://www.oregon.gov/odf/Documents/forestbenefits/asian-giant-hornet-1.pdf
- https://www.oregon.gov/odf/Documents/forestbenefits/asian-giant-hornet-2.pdf

FOREST DISEASES

Figure 31. Ponderosa pine with stem infection of dwarf mistletoe (Gabriela Ritokova, ODF).

Gilchrist State Forest (GSF) is a 65,000-acre State Forest in Klamath County and managed by the Oregon Department of Forestry. It was previously managed by a family forestry company followed by industry before being acquired by the State. Ponderosa pine and lodgepole pine dominate the forest, while sugar pine is abundant at higher elevations. One of the primary forest pests influencing the timber value and productivity of trees in the forest is dwarf mistletoe. **Dwarf mistletoes** are native parasitic flowering plants that infect conifers. Although a few plants in a tree crown have no real impact on the tree, a severely infected tree with abundant infections has reduced growth and stem deformation and may have tree-top and branch dieback. On the positive side, dwarf mistletoes benefit wildlife by creating habitat and nesting sites. On the GSF, two dwarf mistletoes are present: western dwarf mistletoe (*Arceuthobium campylopodum*) on ponderosa pine (Fig. 31) and lodgepole pine dwarf mistletoe (*A. americanum*) (Fig. 32). These two species are generally host-specific, although western dwarf mistletoe has been observed infecting lodgepole pine on several occasions.

Using a systematic grid of locations across the forest, trees were sampled using the Hawksworth dwarf mistletoe rating system, where each tree crown is divided into thirds. Each third is assigned a number between 0 and 2 (0 = no dwarf mistletoe, 1 = <50% of the branches infected, 2 = >50% of branches infected). Each third is summed for a total tree rating of 0 (no infections) to 6 (severely infected). We found western dwarf mistletoe and lodgepole pine dwarf mistletoe were common on ponderosa and lodgepole pine but were not everywhere. No dwarf mistletoe was observed on sugar pine. A total of 6,345 trees were surveyed in 39 plots, 7.9% of ponderosa pine and 9.4% of lodgepole pine were infected indicating a manageable situation. The mistletoe distribution across the forest suggests a generally clustered presence, with significant areas being free of dwarf mistletoe (Fig. 34). The incidence of dwarf mistletoe consisted of western dwarf mistletoe in 33% of plots and lodgepole pine dwarf mistletoe in 33% of plots. Of the trees that were infected, the average dwarf mistletoe rating was 3.6 for ponderosa pine and 2.3 for lodgepole pine, indicating that where dwarf mistletoe occurs, it can be severe. Figure 33 (from Hawksworth and Wiens 1996) lists the growth losses associated with the rating of individual trees.

Figure 32. Witches broom symptom (i.e., dense mass of overgrowth) in ponderosa pine caused by dwarf mistletoe (left) and mistletoe in lodgepole (right) Gabriela Ritokova, ODF).

Percent growth of infected trees							
Arceuthobium species	**Host**	**Class 1**	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
A. americanum	*P. contorta*	100	100	100	94	80	59
A. campylopodum	*P. ponderosa*	100	100	98	86	73	50

Figure 33. Relative rates of diameter growth in relation to the intensity of infection by Arceuthobium as quantified with the 6-class dwarf mistletoe rating system (DMR). From Hawksworth and Wiens 1996. Note: Diameter growth rates of uninfected trees taken as 100%. Percentages based on averages of several studies throughout the western United States (adapted from Hawksworth and others 1992).

Dwarf mistletoe spreads by an explosive discharge of the seed, which propels the seeds up to 35 feet. This differs from most of the world's mistletoe which is dispersed by birds. Dwarf mistletoe distribution is generally aggregated on the landscape, and severely infected trees will occur in distinct infection centers. This manner of seed dispersal means that forest composition, density, and structure control the local spread of dwarf mistletoe. Dwarf mistletoe spreads into uninfected areas at a rate of about 2 feet/year. However, non-host trees block the spread, while very dense stands of host trees slow the spread. In uneven aged stands, the dominant canopy position trees may be infected, and they can "rain down" seeds from above and infect regenerating trees.

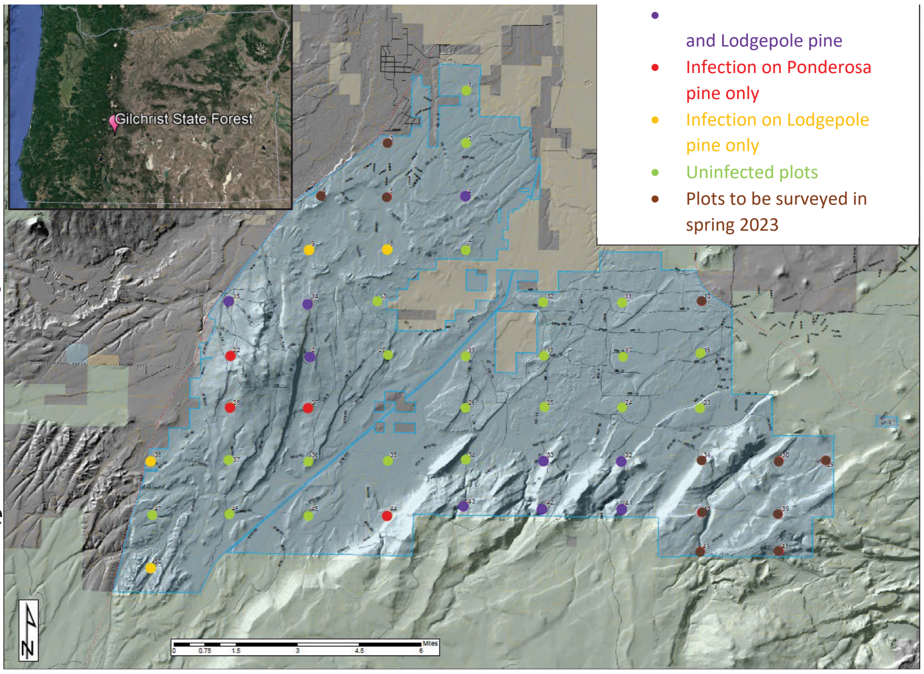


Figure 34. Map of mistletoe plot distribution on the GSF. Purple dots signify infections on ponderosa and lodgepole pines, red dots are infections on ponderosa and yellow dots are infections on lodgepole, green dots represent uninfected plots and brown dots are plots to be surveyed in spring 2023.

The primary natural control of dwarf mistletoe is fire. Fire history and patterns control the overall distribution of dwarf mistletoe on the landscape. The GSF area likely had a combination of regular low-intensity fire burn through ponderosa pine-dominated areas and mixed severity fires in areas with pure lodgepole pine or the mixed forests of ponderosa, lodgepole, and sugar pine. Although fire is very important in defining where dwarf mistletoe occurs, fire suppression has removed fire as an active control agent for dwarf mistletoe and replaced it with forest management and harvesting practices. High-grading (i.e., removal of high-value trees and often leaving behind lower quality or less vigorous trees) can allow the persistence and spread of dwarf mistletoe, while fire suppression increases the density and homogeneity of host species.

Foresters in the GSF are returning to a sustainably harvested, uneven-aged structure model to manage the dwarf mistletoe. The goal is to limit the negative impacts of dwarf mistletoe on overall timber production but not eradicate the native plant. Silvicultural techniques to reduce stand-level dwarf mistletoe ratings include minimizing the retention of heavily infected overstory leave-trees, cutting and thinning heavily infected understory trees, planting non-host trees around infection areas or around heavily infected leave-trees, applying prescribed fire, and creating gaps where heavily infected trees are aggregated.

FOREST DISEASES

Sudden Oak Death (SOD) is caused by the non-native pathogen *Phytophthora ramorum*. In Oregon, it kills tanoak (*Notholithocarpus densiflorus*) readily, by causing girdle-creating canker lesions on the main stem (Fig. 35) and threatens the species throughout its natural range. *P. ramorum* has a broad host range of over 100 plant species, including several species native to Oregon's forests. The pathogen survives in Oregon's wet and cool coastal climate, spreading during rainy and windy periods from trees onto other trees, shrubs, and adjacent vegetation. The disease can be spread by wind as far as 3-5 miles per year. Humans contribute to disease spread by moving infected material, whole plants, plant parts, or infested soil.

Figure 35. SOD symptoms: canker lesions underneath the bark (Gabriela Ritokova, ODF).

The disease was first discovered in coastal southwest Oregon forests in July 2001. Since then, an interagency team has continued to slow the spread of the pathogen through a program of early detection and treatment of infected and adjacent host plants. Treatments include cutting and burning infected and potentially exposed host material. The spread of *P. ramorum* is managed through the designation of a SOD Generally Infested Area (GIA) and SOD quarantine area under the authorities of the ODA (ORS 603-052-1230) and USDA APHIS (7 CFR 301-92). These state and federal quarantines regulate the intrastate and interstate movement of host plant material outside the quarantine area. Oregon regulations require infested sites on state and private lands to undergo eradication treatment.

Oregon SOD staff conduct multiple surveys throughout the year to monitor disease spread and detect new infestations. These include aerial surveys, ground-based transects, and stream monitoring. In 2022, multiple fixed-wing aerial surveys to monitor disease spread and detect new infestations covered a total of over 420,000 acres. This special survey, conducted annually (with the exception of the 2020 and 2021 COVID-affected years), is staffed by ODF and USFS surveyors, who fly a 2-mile grid from the California border to the Curry/Coos County line. Other SOD survey and detection (see SOD GIS dashboard) efforts continued in, and adjacent to, the SOD quarantine area throughout 2022. These include monitoring at 60 stream bait sites, aerial imagery interpretation of 379,000 acres, and 469 acres of ground transect surveys for the permitted harvesting of disease-free tanoak. Tanoak harvest is only allowed by landowner petition to the Oregon Department of Agriculture for a special permit under OAR 603-052-1230, Oregon's *P. ramorum* quarantine.

Following detections outside of the SOD Quarantine in 2021, in 2022 ODF continued to aggressively treat all known NA2 infestations in the Port Orford area with large buffers of 300-600 feet (Fig. 36). No new *P. ramorum* infestations were detected outside of the SOD Quarantine Area in 2022 (Fig. 37). From 2001 through 2022, eradication treatments have been completed on more than 8,200 acres at an estimated cost of over $35 million.

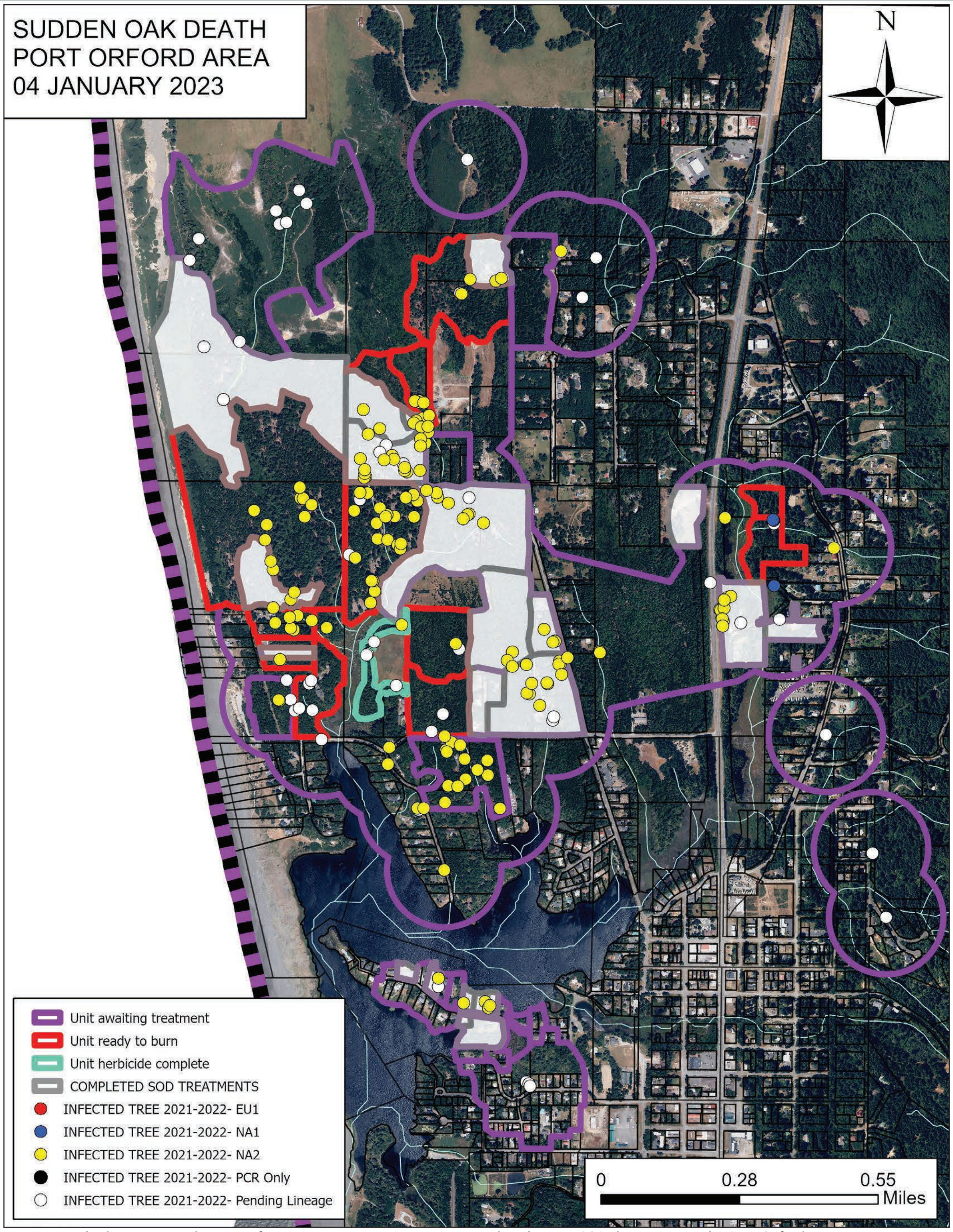


Figure 36. The locations and status of management activities associated with 2021 SOD detections in the Port Orford area.

Sudden Oak Death resources:
SOD GIS dashboard: https://tinyurl.com/oregonsod
Forest operations guide within SOD quarantine areas: https://tinyurl.com/9zvmdbht
Additional information:
https://www.oregon.gov/oda/programs/PlantHealth/Pages/SODProgram.aspx
https://catalog.extension.oregonstate.edu/em9216
https://www.aphis.usda.gov/plant_health/plant_pest_info/pram
https://www.suddenoakdeath.org/

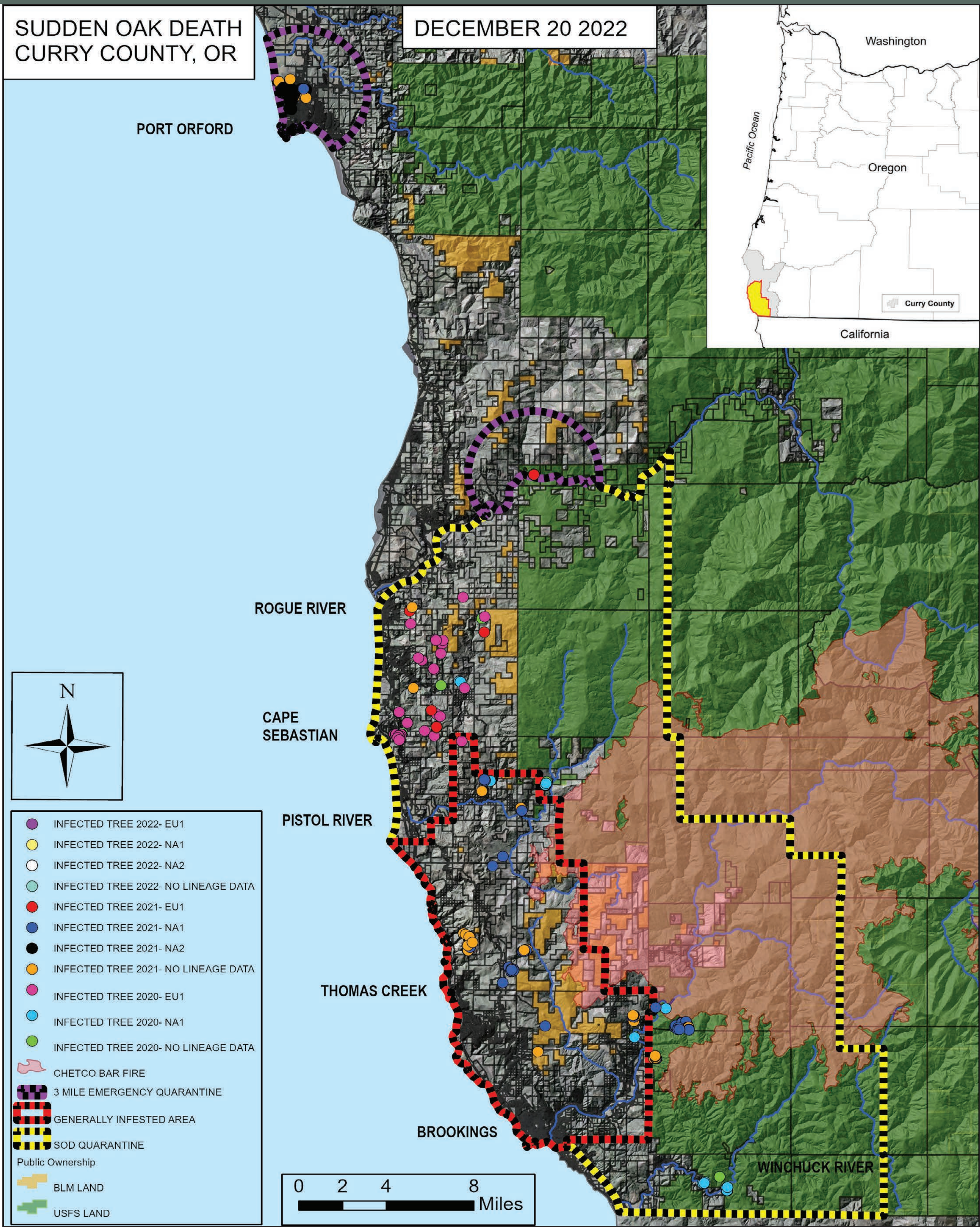


Figure 37. Map of the SOD Generally Infested Areas (red) and quarantine area (yellow). EU1 and NA1 are two different lineages of P. ramorum. In Europe, the EU1 lineage kills or damages conifer tree species and is considered more aggressive than the NA1 lineage.

Sooty bark disease (SBD) of maple (Acer) is caused by the fungus *Cryptostroma corticale* and has only recently emerged as a growing urban forest concern in the Pacific Northwest and British Columbia. Prior to this recent emergence, the pathogen was introduced to Europe from its native range in the Great Lakes Region, where it's considered a saprophyte, surviving on dead and decaying organic matter. In Europe *C. corticale* has been causing dieback primarily in Sycamore maples (*Acer pseudoplatanus*), although several other species have been confirmed as hosts in the Pacific Northwest, including natives such as bigleaf maple (*A. macrophyllum*) and Pacific dogwood (*Cornus nuttallii*), and non-natives such as red maple (*A. rubrum*), and horse chestnut (*Aesculus hippocastanum*). In Oregon, the pathogen was found in Bend on Norway maple (*Acer platanoides*), and Freeman maple (*Acer* × *freemanii*) (Fig. 38), and on vine maple (*Acer circinatum*) in the Portland area. Infected trees had dieback symptoms and visible fungal growth on bark surfaces (Fig. 38) and beneath the bark (Fig. 39).

Figure 38. Freeman maple with signs of SBD (Brent Oblinger, USFS).

The fungus infects and kills smaller branches, then spreads into the heartwood, causing cankers and ultimately killing the tree. It thrives at higher temperatures and appears after hot summers or prolonged drought periods. The disease is not found in high elevations or near coastal areas with cooler and wetter weather patterns. Under conducive environmental conditions, the fungus rapidly grows within the tree, causing tree bark to split open, revealing stromatal tissue covered with dark grey-black spore masses resembling soot. These spores can be carried long distances by wind. They may cause an allergic reaction in susceptible people, which has been a problem for those working around diseased maples. Arborists, loggers, or millworkers working with infected plant material should wear personal protective equipment to minimize spore inhalation and avoid contracting hypersensitive pneumonitis.

Figure 39. Bigleaf maple tree with sooty bark disease signs (sunken black fungal mats (Rachel Brooks, WDNR).

The distribution, host range, and impact of SBD in Oregon are currently unknown. A statewide field survey and subsequent research are needed to determine the distribution of SBD and the long-term consequences this pathogen will have on our forest and urban ecosystems. ODF, USFS, OSU, and municipal staff and arborists are collaborating in the survey effort, monitoring, and research development of this emerging threat. In the spring and summer of 2023, the collaborators aim to conduct surveys throughout Oregon and provide disease diagnostics.

FOREST DISEASES

Swiss needle cast (SNC), an endemic foliar disease of Douglas-fir, is caused by the fungus *Nothophaeocryptopus gaeumannii*. This disease has been prominent in coastal Douglas-fir forests since the 1990s, particularly along the northern Oregon coast. Early research attributes epidemic levels of SNC to: post-harvest species-conversion to Douglas-fir within coastal stands, changes in climate, and planting of off-site seed sources from areas with lower disease pressure and tolerance.

Figure 40. SNC causes foliage loss and sparse yellow crowns in Douglas-fir, reducing volume growth (Gabriela Ritokova, ODF).

Healthy Douglas-fir trees typically retain foliage for 3-7 years, however, SNC-infected trees suffer from premature needle loss and the most infected trees may retain as little as one year of foliage. Premature needle loss is most obvious in the tops of trees during the late spring prior to bud break, resulting in yellowing needles and sparse crowns (Fig. 40). Infected trees appear yellow and can be identified via aerial survey (Fig. 41-43).

Premature foliar loss has a significant effect on the growth and yield of infected Douglas-fir plantations. A 2008 analysis of SNC-related volume growth loss found that 10-30 year old Douglas-fir plantations along the northern Oregon coast were experiencing an average annual cubic volume growth loss of approximately 22%, with the most infected stands exhibiting volume growth losses of as high as 50%. Subsequent analyses have shown that volume growth losses in the Oregon Coast Range exceed 190 million board feet per year. Although SNC rarely kills Douglas-fir, it can reduce its growth to the point where it can be outcompeted by species such as western hemlock. The effect of SNC on canopy density and light penetration can have profound effects on stand development, and differentiation and development of wildlife habitat and structure both within and below the tree canopy.

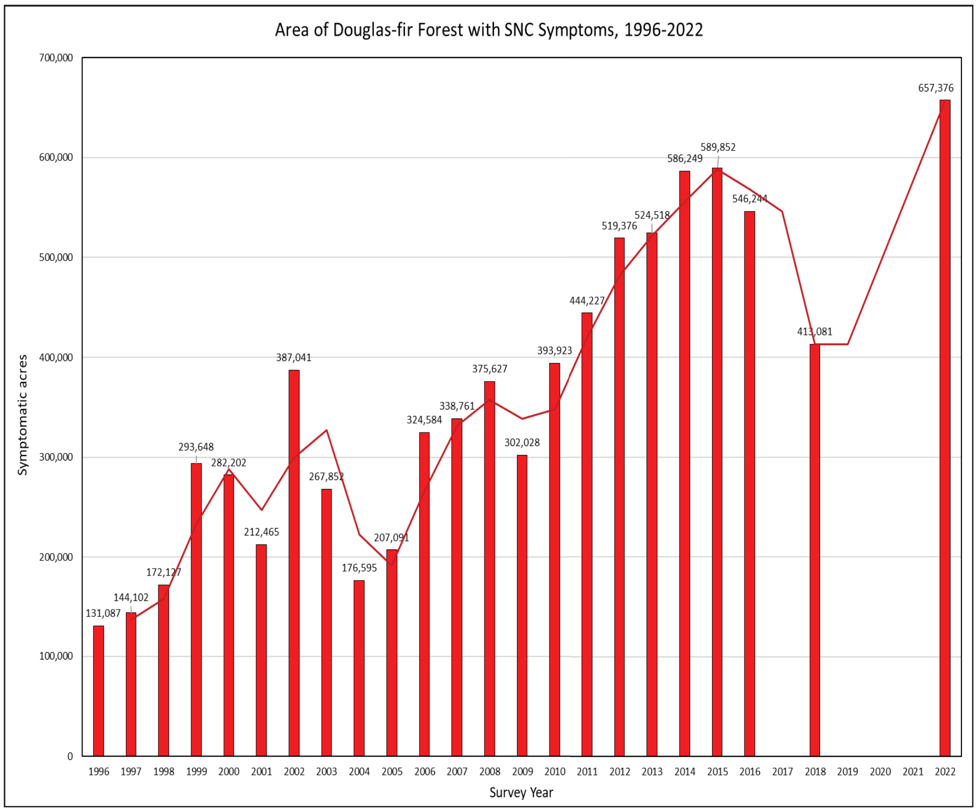


Figure 41. Area of Douglas-fir forests in western Oregon with symptoms of SNC detected during aerial surveys flown in spring 1996 – 2022. Some years (2017, 2019-2021) SNC was not surveyed due to changes in methods and COVID-19 interruptions.

SNC research continues on a network of 106 plots distributed throughout the Oregon Coast Range and into southwest Washington that was established in 2013-2015 by the Swiss needle cast Research Cooperative at Oregon State University. This network was established to provide updated information on disease severity and distribution, Douglas-fir growth and yield, and provide a framework for addressing other SNC research questions. The first remeasurement of the updated plot network has already shown that cubic volume growth losses in the most heavily infected stands are at about 35%, a lower value than originally estimated in 2008. This lower number is thought to be due to the post-harvest replacement of Douglas-fir with western hemlock in coastal zones that are subject to the greatest intensity of disease pressure and demonstrating the poorest growth performance. Remeasurement data from the plot network has been used to estimate diameter and height increment modifiers, enabling the simulation of SNC-infected stands with growth models.

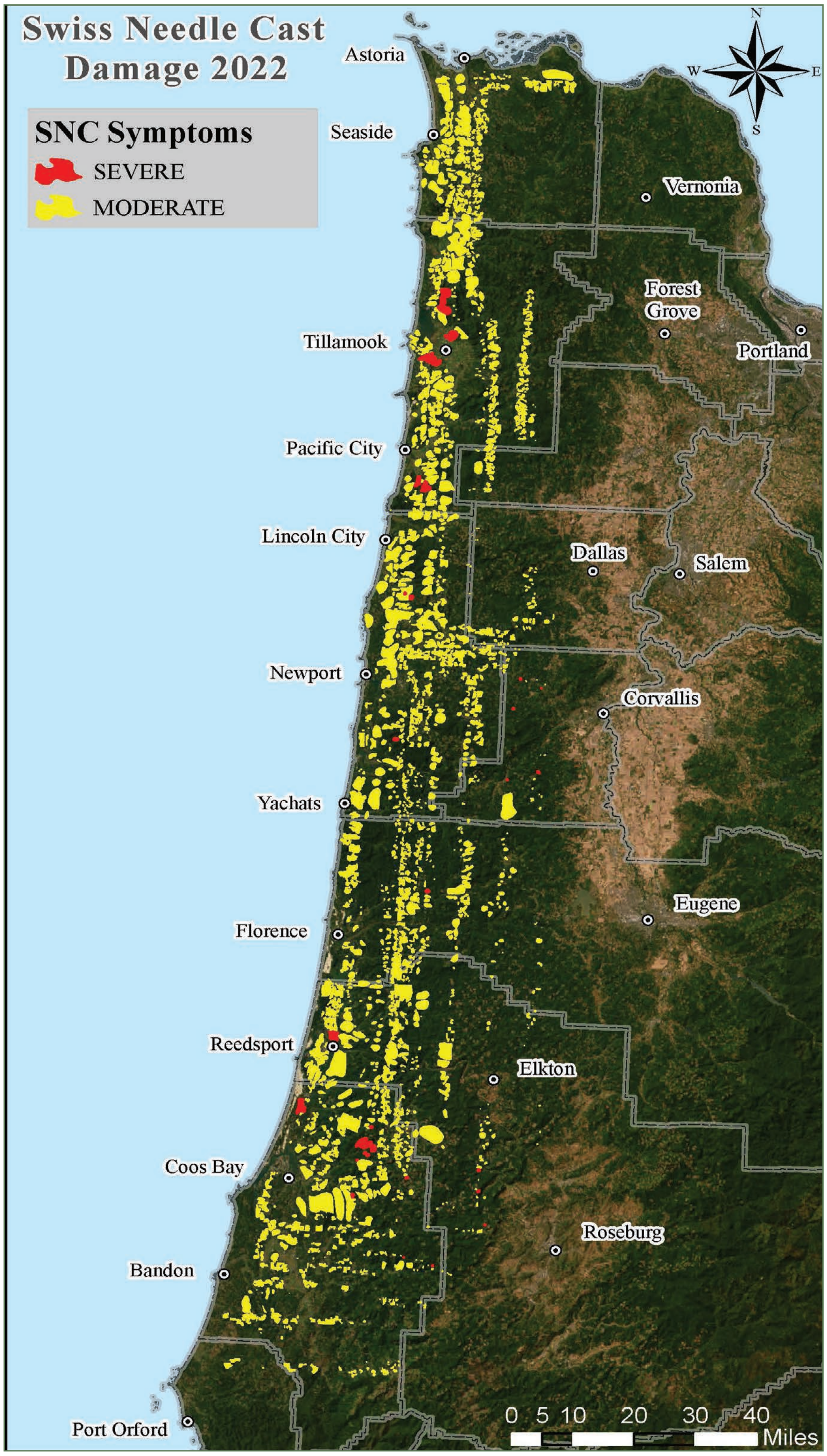


Figure 43. Map of areas with SNC symptoms detected in 2022 during SNC aerial survey.

Figure 42. Heavily infected Douglas-fir stand with brown symptoms to the right of a green stand of western hemlock which is resistant to SNC.

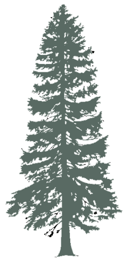
Swiss needle cast resources:
http://tinyurl.com/odf-foresthealth
https://sncc.forestry.oregonstate.edu

IMPORTANT INSECT AND DISEASE PESTS

	DOUGLAS-FIR	TRUE FIR	PINE
INSECTS	 • Douglas-fir beetle • Douglas-fir tussock moth • Western spruce budworm • Flatheaded fir borer • Cooley spruce gall adelgid* • Douglas-fir pole & engraver beetles*	 • Douglas-fir tussock moth • Western spruce budworm • Fir engraver beetle • **Balsam woolly adelgid**	 • Ips beetles (pine engraver & California five-spined) • Mountain pine beetle • Western pine beetle (ponderosa only) • Pine butterfly • Black pineleaf scale • Sequoia pitch moth*
DISEASES	• Laminated root rot • Blackstain root disease • Armillaria root disease • Swiss needle cast • Rhabdocline needle cast • Douglas-fir dwarf mistletoe • Heart and stem decays	• Annosus root disease • Interior needle blight • Fir needle rust • Fir broom rust • Heart and stem decays	• **White pine blister rust** (5-needle pines) • Diplodia tip blight • Dothistroma needle blight • Western gall rust • Blackstain root disease • Armillaria root disease • Pine dwarf mistletoes

	TANOAK	WHITE OAK	MAPLE
INSECTS	• **Spongy moth complex** 	• **Spongy moth complex** • **Mediterranean oak borer** • Oak looper* • Gall-making wasps & flies* • Leaf miners* 	• **Asian longhorned beetle** • **Spongy moth complex** • Various defoliators* 
DISEASES	• **Sudden oak death** (*Phytophthora ramorum*) • Armillaria root disease	• Armillaria root disease • Inonotus trunk rot	• Tar spot • Ganoderma trunk rot • Armillaria root disease • Sooty bark disease

*Secondary or aesthetic pests that are not typically tree-killers
BOLD: non-native, exotic insects and diseases

HEMLOCK	SPRUCE	'CEDARS'	LARCH
 • Western hemlock looper	 • Spruce beetle • **Spruce aphid** • Cooley spruce gall adelgid*	 • Cedar bark beetles* • Amethyst borer* • Western cedar borer*	 • **Larch casebearer**
• Annosus root disease • Hemlock dwarf mistletoe • Hemlock needle rust • Heart and stem decays	• Spruce broom rust • Heart and stem decays	• **Port-Orford-cedar root disease** (POC only) • Cedar leaf blight (western redcedar only)	• Larch needle cast • Larch needle blight • Larch dwarf mistletoe

ALDER	ASH	POPLAR	MADRONE
• **Spongy moth complex** • Western tent caterpillar* • Alder flea beetle* 	• **Emerald ash borer** • **Spongy moth complex** 	• **Spongy moth complex** • **Satin moth*** • Webworm* 	• **Spongy moth complex** • Webworm* 
• Armillaria root disease • Nectria canker • Alder collar rot • Heart and stem decays		• Heart and stem decays	• Madrone leaf blight • Madrone branch dieback • Madrone stem cankers

Don't know your tree? ID here:

Oregon tree ID: https://oregonstate.edu/trees/name_common.html

FOREST HEALTH CONTACTS

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2600 State Street, Salem, OR 97310
https://tinyurl.com/odf-foresthealth

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Wyatt Williams	Invasive Species Spec.	(503) 798-5436	wyatt.williams@odf.oregon.gov
Harold Stevens	Aerial Survey Spec.	(503) 302-4259	harold.a.stevens@odf.oregon.gov

USDA Forest Service – Forest Health Protection and Forest Health Monitoring Programs
1220 SW Third Avenue, Portland, OR 97204
https://www.fs.usda.gov/main/r6/forest-grasslandhealth/insects-diseases

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