Forest Service
United States Department of Agriculture

Oregon Department of Forestry
Forest Health

Pacific Northwest Region

Forest Health Highlights in Oregon - 2023

FOREST HEALTH HIGHLIGHTS IN OREGON - 2023

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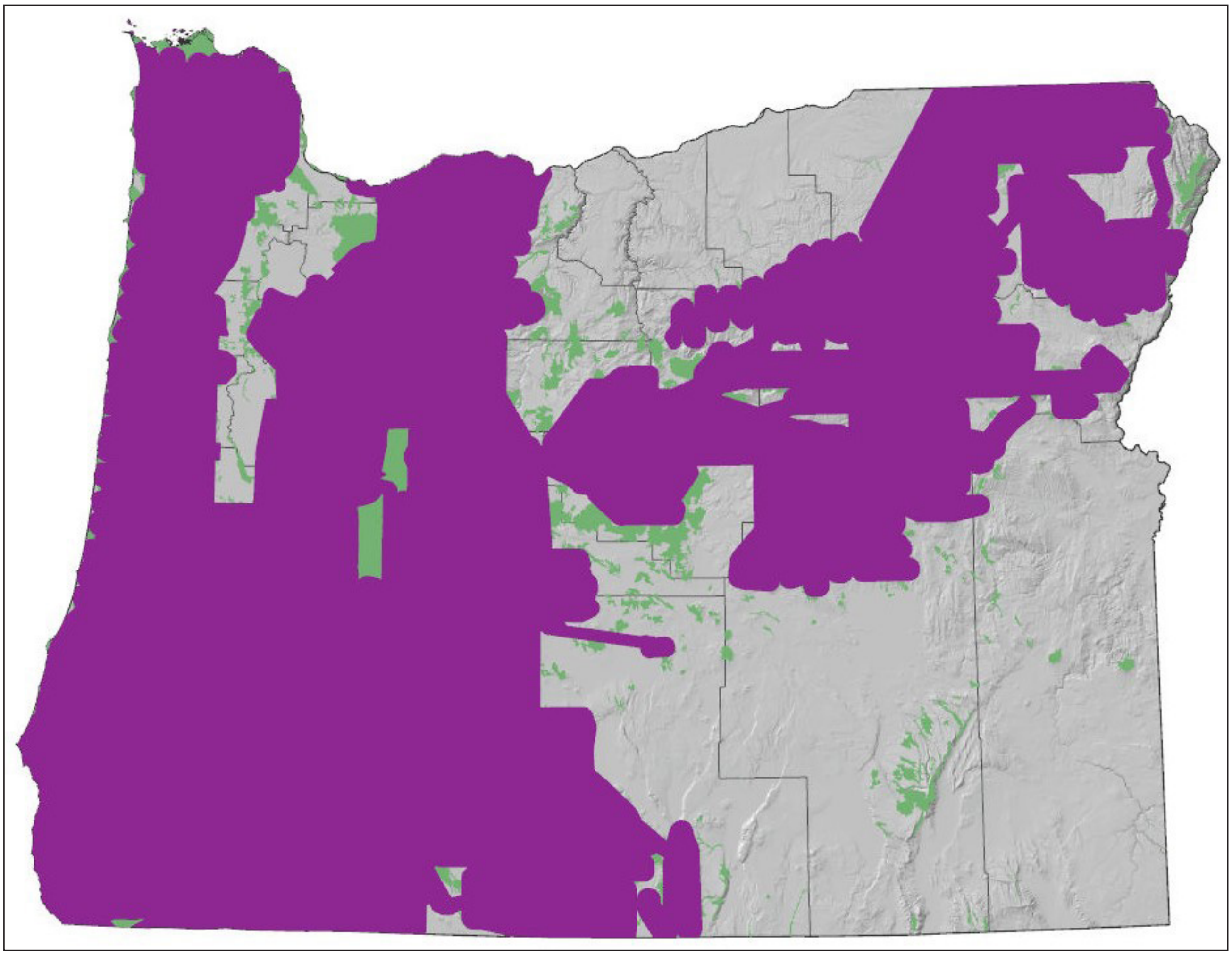
Cooperative Aerial Survey: 2023 coverage area



Map above: *In 2023 the cooperative USFS and ODF aerial survey covered 37 million acres (purple) across forested portions of the state (green). Some forested areas are not surveyed due to airspace restrictions, current-year wildfire mortality, etc.*

Front cover: *Emerald ash borer (left) and Mediterranean oak borer (right) are exotic, invasive woodboring beetles recently detected in Oregon that threaten ash and oak trees, respectively (Christine Buhl, ODF).*

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LANDOWNER RESOURCES

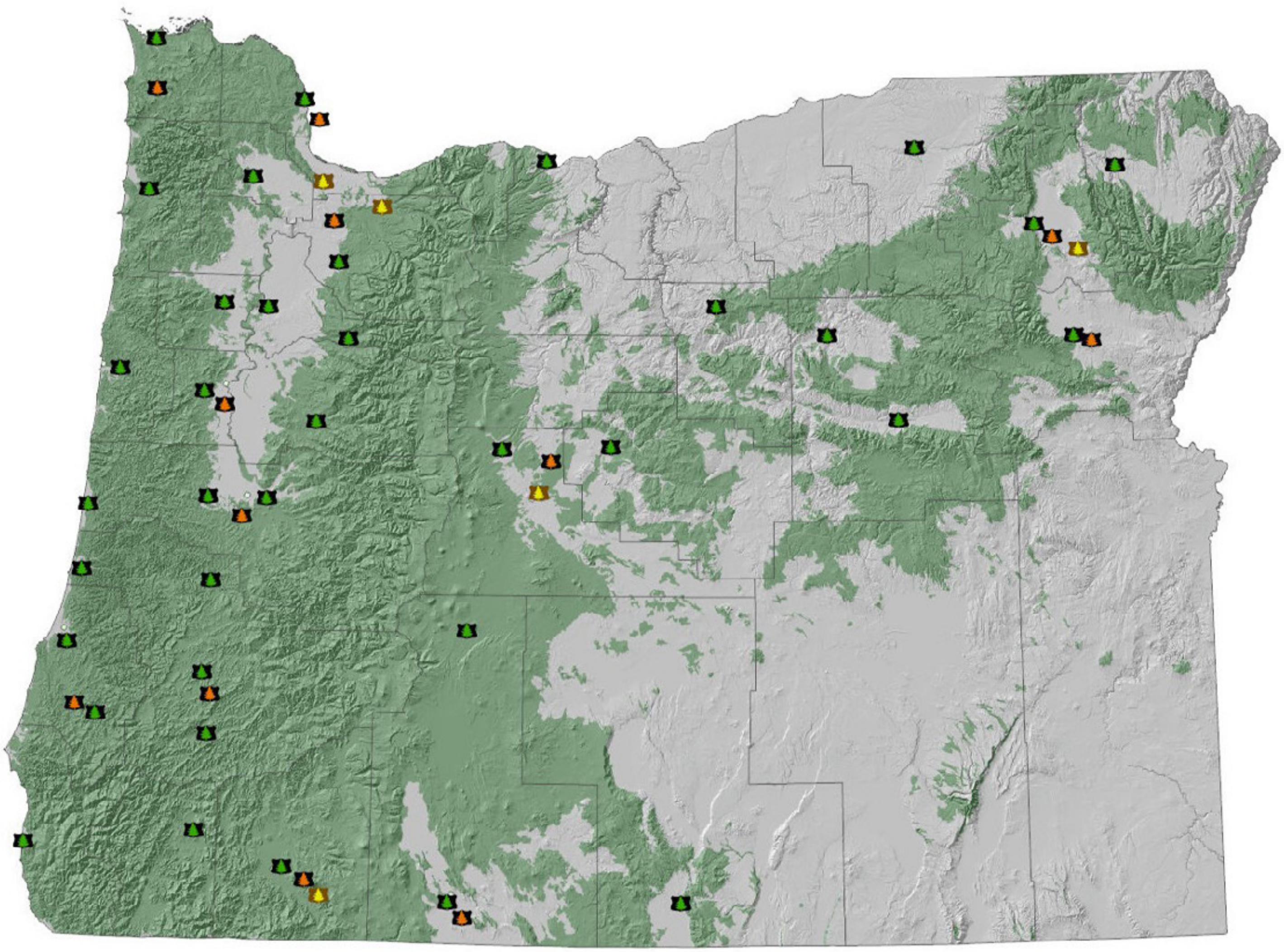


Figure 1. Map of office locations for ODF (green tree), USFS (yellow tree), and OSU Forestry Extension (orange tree).

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

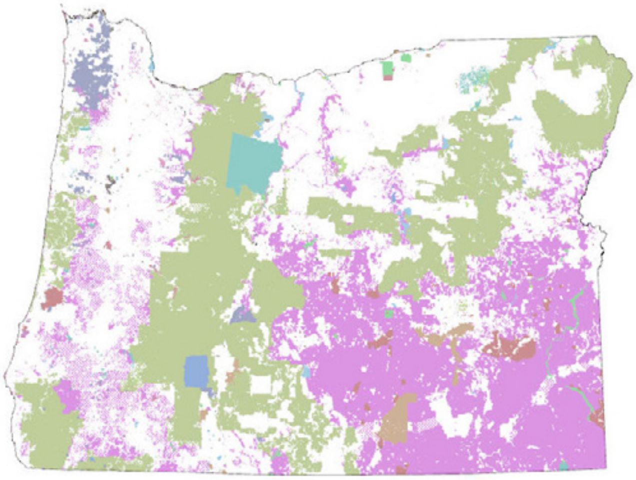


Figure 2. The majority of land ownership in Oregon is private (white) and public land managed by BLM (pink) and USFS (green).

Forestry has a long and storied history in the Pacific Northwest, especially in Oregon which, at 30 million acres, is almost half forestland. These numbers have remained relatively consistent since 1953. These forests include family-owned forests that are handed down across generations, large tracts of productive industrial land, and untouched wilderness (Fig. 2). Oregon offers a diversity of forests ranging from: mossy rain-drenched coastal ecosystems dominated by Sitka spruce, Douglas-fir, red alder, and western hemlock, to semi-arid mixed conifer forests dominated by lodgepole, ponderosa and sugar pine, and Douglas-fir, incense cedar, and western larch (Fig. 3). 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 sagebrush steppe. 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. Oregon's forests consist of federal (60%), private (35%), state (3%), tribal (1%), and other public (1%) ownerships.

Figure 3. 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. In 2023, changes to the FPA, which improve aquatic species and natural resource protections (Private Forest Accord SB 1501, SB 1502, HB 4055), went into effect. Private forest landowners may also opt to comply with additional growth and harvest requirements as part of various certification programs (e.g., Sustainability Forestry Initiative, American Tree Farm System, Forest Stewardship Council, etc.). Federal and tribal lands are managed under Northwest Forest Plan policies (Est. 1994), which entered a review process in 2023 to improve climate-informed strategies. Oregon forests have been struggling with climate change-related damage such as ongoing droughts and intensified wildfires. 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.

2023 FOREST HEALTH SUMMARY

Abiotic, insect, and disease disturbance agents can cause significant tree mortality, growth loss, and damage in Oregon forests each year. Non-native pests can cause direct tree mortality and most of our native pests only present a problem when trees are stressed and their defenses are reduced. Often a complex of factors contributes to tree stress and weakened defenses ([Manion 1991 decline spiral model of cumulative impact of multiple stresses on trees]). 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 tree susceptibility to opportunistic insects and diseases.**

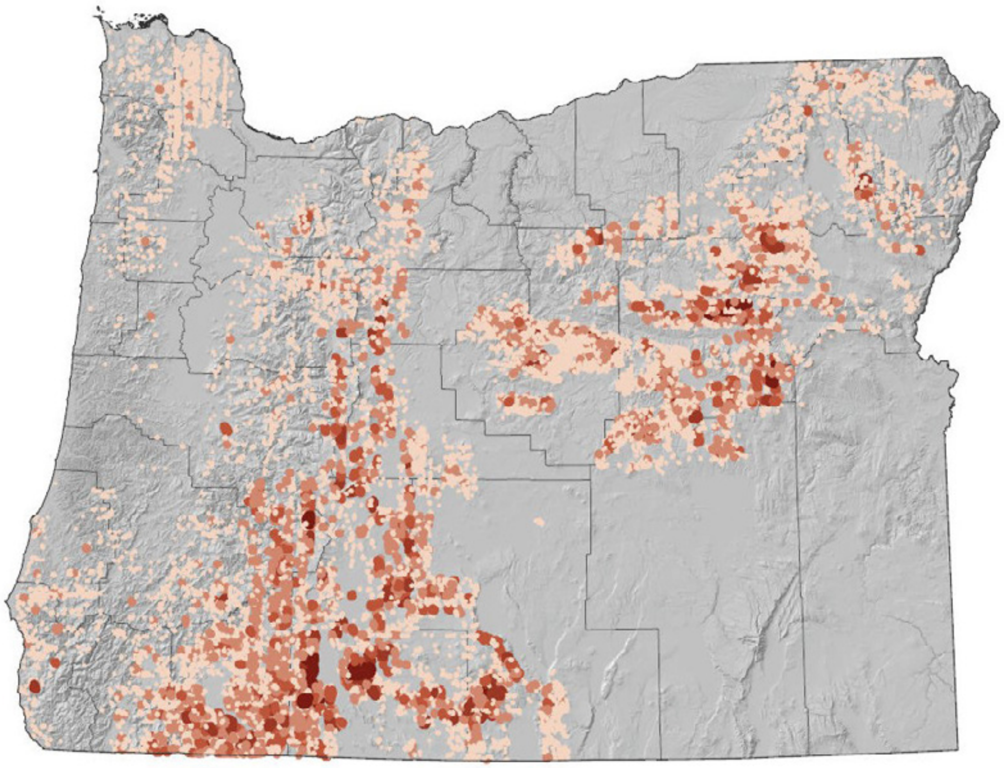


Figure 4. Intensity map (increasing light to dark) of insect, disease, and abiotic (non-wildfire) damage and mortality observed in the 2023 aerial survey. Perimeters enhanced for visibility.

This report highlights major agents of damage and mortality in Oregon forests over the past year and provides updates on chronic issues. Damage and mortality trends (Figs. 5 and 6) and maps (Figs. 4 and 7) are produced from aerial and ground surveys. We rely on reports from ODF, USFS, and OSU forestry staff from offices around the state (Pg. 1 and back cover). Additionally we collaborate with other natural resource agencies, universities, public and private forest landowners and managers, and members of the general public to gather information. In recent years drought stress has been a major underlying cause of tree dieback and decline - often followed by subsequent attack by opportunistic insects such as bark beetles. Aerial surveys identified the largest amounts of tree damage and mortality in areas that are the hardest hit by drought (Fig. 4). Most years damage from drought and subsequent insect attack is higher than, or at least comparable to, acres of damage and mortality from wildfire (Figs. 5, 6, and 11). 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 (Pg. 15). Another widespread stressor that weakens trees and further predisposes them to the effects of droughts and reduces resilience to insects is root disease. Although trees can tolerate some root diseases for many years, these pathogens spread out from epicenters, are hard to detect via aerial surveys, require extensive ground surveys to evaluate, and, when identified, are hard to eradicate or mitigate.

2023 FOREST HEALTH SUMMARY

Temperature and precipitation greatly influence tree health and resilience against insects and diseases. Our last year of La Niña in 2023 provided many parts of Oregon with cooler temperatures and increased precipitation (including snowpack), which gave trees a brief period to repair from prior droughts. However, the shift back to El Niño early in the growing season increased drought levels for many parts of the state.

In 2023, across our 30 million acres of forest we observed a mosaic of damage and mortality that comprised about 2.6 million acres. The cause of this damage includes insects, diseases, and abiotic stressors such as wildfire. Damage from insects, diseases, and non-wildfire agents, relative to area surveyed, was about 20% lower than in 2022, although twice as high as the 10-year average (data from 2020 excluded due to non-comparable collection methods). For wildfire, we saw a 50% reduction of acres damaged relative to 2022 and a 65% reduction from the 10-year average.

Although our mapping technique and software is relatively accurate in recording only damaged and recently dead trees while excluding healthy and older dead trees, recorded areas of damage include stressed, recently dead, and some healthy trees. Not all damage to our forests is captured. For example, many diseases go undetected or are only surveyed every other year (e.g., Swiss needle cast), and others may not be visible at the time of surveys. However, some disease totals are captured and folded into other measurements; for example, as much as 80% of "young conifer mortality" (historically mislabeled as "bear") may result from root diseases rather than vertebrate damage (Taylor et al. 2019).

Forest health encompasses all of these damage agents: insects, disease, abiotic (wildfire and non-wildfire). Luckily, management strategies to promote tree resilience and maintain stand health increase resistance and/or tolerance to many of these agents including drought stress, insect infestation, and high intensity wildfires.

Year	Insect[(a)]	Disease[(b)]	Young conifer mortality	Abiotic (non-wildfire)	Unknown	Acres flown	Proportion of non-wildfire damage relative to acres flown	Wildfire
2014	497,206	32,963	39,111	75	6,105	36,131,000	2%	984,629
2015	527,088	34,538	59,121	2,976	3,007	36,027,078	2%	685,809
2016	586,960	21,199	40,047	51	3,245	36,099,637	2%	192,557
2017	523,208	9,998	29,072	4,811	635	35,263,946	2%	644,141
2018	666,214	11,910	22,072	2,128	240	36,151,968	2%	883,338
2019	694,066	12,311	25,841	13,625	4,448	35,672,506	2%	78,989
2020[(c)]	-	-	-	-	-	-	-	-
2021	360,322	4,863	34,756	149,733	29,332	24,782,940	2%	672,345
2022	1,974,746	698,409	14,480	26,016	27,879	33,418,549	8%	445,858
2023	2,285,042	47,923	59,117	2,875	11,261	37,265,980	6%	206,078
2022	1,974,746	698,409	14,480	26,016	27,879	33,418,549	8%	445,858
2023	2,285,042	47,923	59,117	2,875	11,261	37,265,980	6%	206,078

Figure 5. Damage and mortality from 2014-2023 from insect, disease, and abiotic (non-wildfire) data collected from annual aerial surveys and wildfire data from the Northwest Interagency Coordination Center.
Caveats to these data include:
(a) Insect damage often indicates underlying stress from a different primary causal agent such as drought.
(b) Not all disease-caused damage can be captured via aerial survey. A large proportion of Young conifer mortality is due to disease. Acres of damage from Swiss needle cast is not included here because it is not an annual survey (Pg. 29).
(c) Data from 2020 are excluded because it was collected via a different method (Scan and Sketch 2020 Forest Health Highlights) that is not comparable across years.

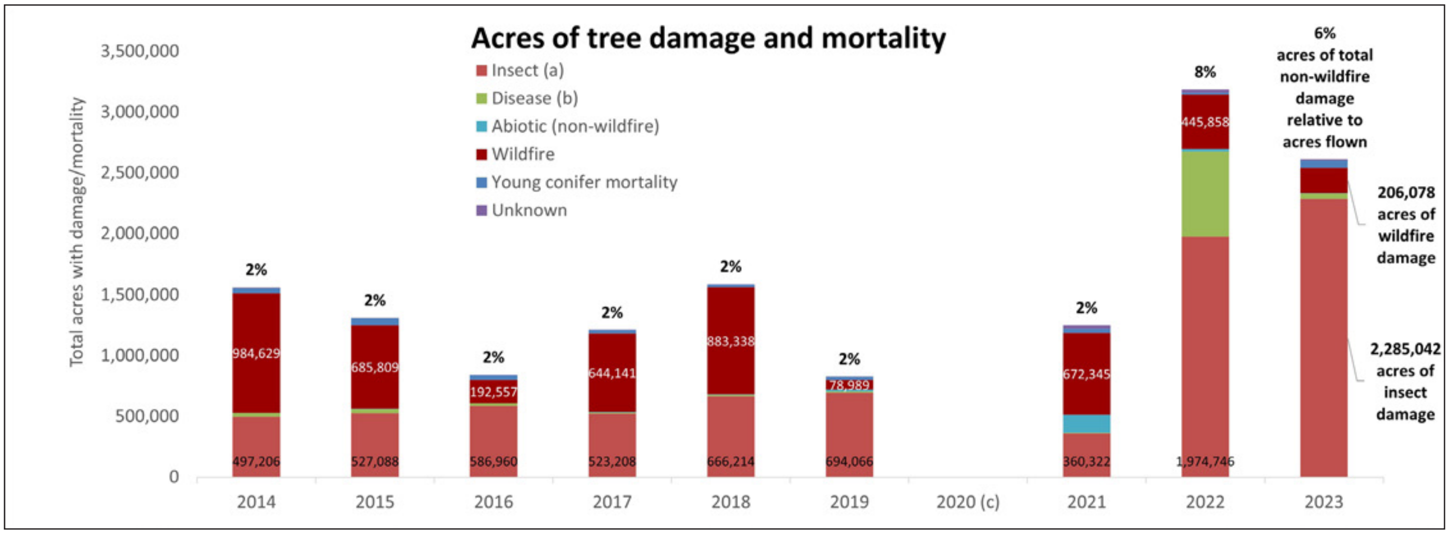


Figure 6. Above: Damage and mortality from 2014-2023 from insect, disease, and abiotic (non-wildfire) data collected from annual aerial surveys and wildfire data from the Northwest Interagency Coordination Center.

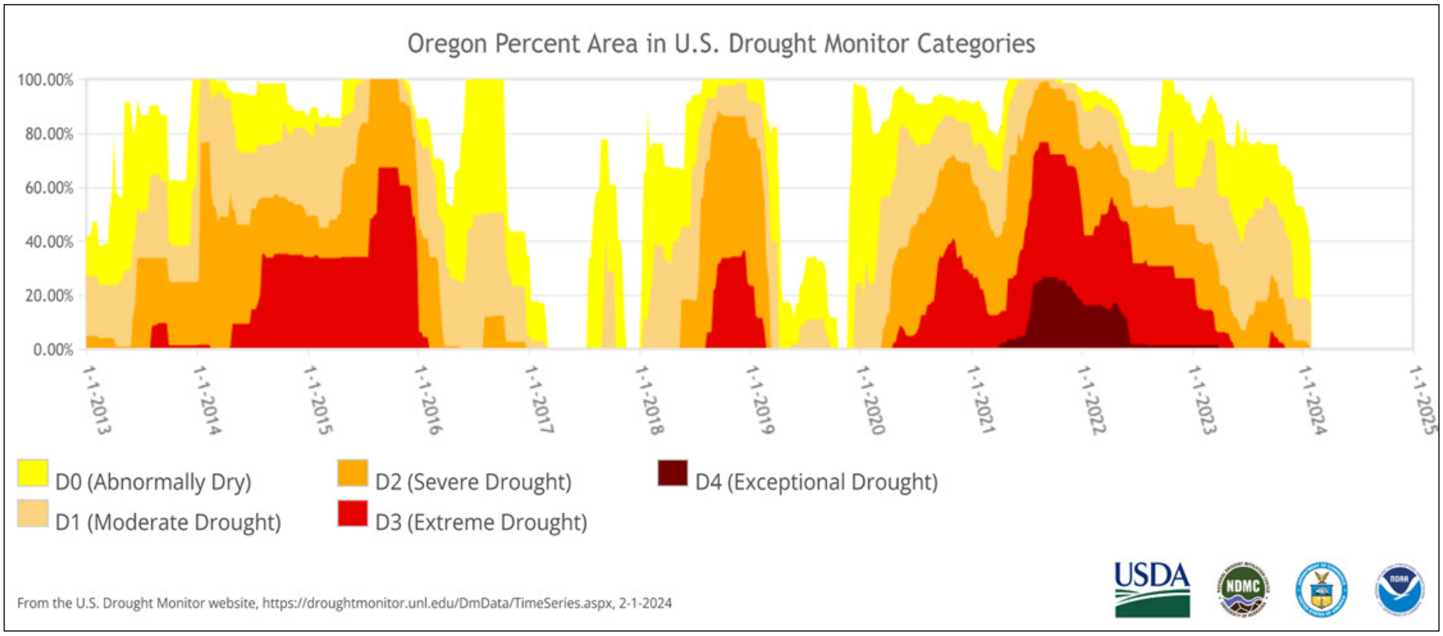
Caveats to these data include:

(a) Insect damage often indicates underlying stress from a different primary causal agent such as drought.

(b) Not all disease-caused damage can be captured via aerial survey. A large proportion of Young conifer mortality is due to disease. Acres of damage from Swiss needle cast is not included here because it is not an annual survey (Pg. 29). The jump in detected disease in 2022 was as a result of increased visibility of cytospora canker disease in true fir.

(c) Data from 2020 are excluded because it was collected via a different method (Scan and Sketch [2020 Forest Health Highlights]) that is not comparable across years.

Below: Graphical time series of annual average statewide drought trends for Oregon from the U.S. Drought Monitor. Drought severity rankings span: 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.



2023 FOREST HEALTH SUMMARY

In 2023, damage and mortality were more concentrated in southern Oregon and along east of the Cascade crest through central to northeastern Oregon (Fig. 7). Damage and mortality were more moderate and scattered west of the Cascades, and even lower along much of the coast but moderate along the southwestern coast. The majority of damage is attributed to bark and woodboring beetles (fir engraver, western and mountain pine beetles, Ips beetles, Douglas-fir beetle, flatheaded fir borer), a defoliator (balsam woolly adelgid), and diseases that cause young conifer mortality and cankers in true fir. Beetles are the largest reported contributor to tree mortality; however, for the most part they are native and symptomatic of other stress such as drought which has weakened tree defenses. The counties in which we observed the greatest amount of tree mortality coincide with those that have experienced the most intense and longest duration drought. Additionally, many of these areas have forests with high stem densities and trees within these forests experience more intense intra- and interspecific competition, and cannot allocate as many resources to defense as can trees in less dense stands.

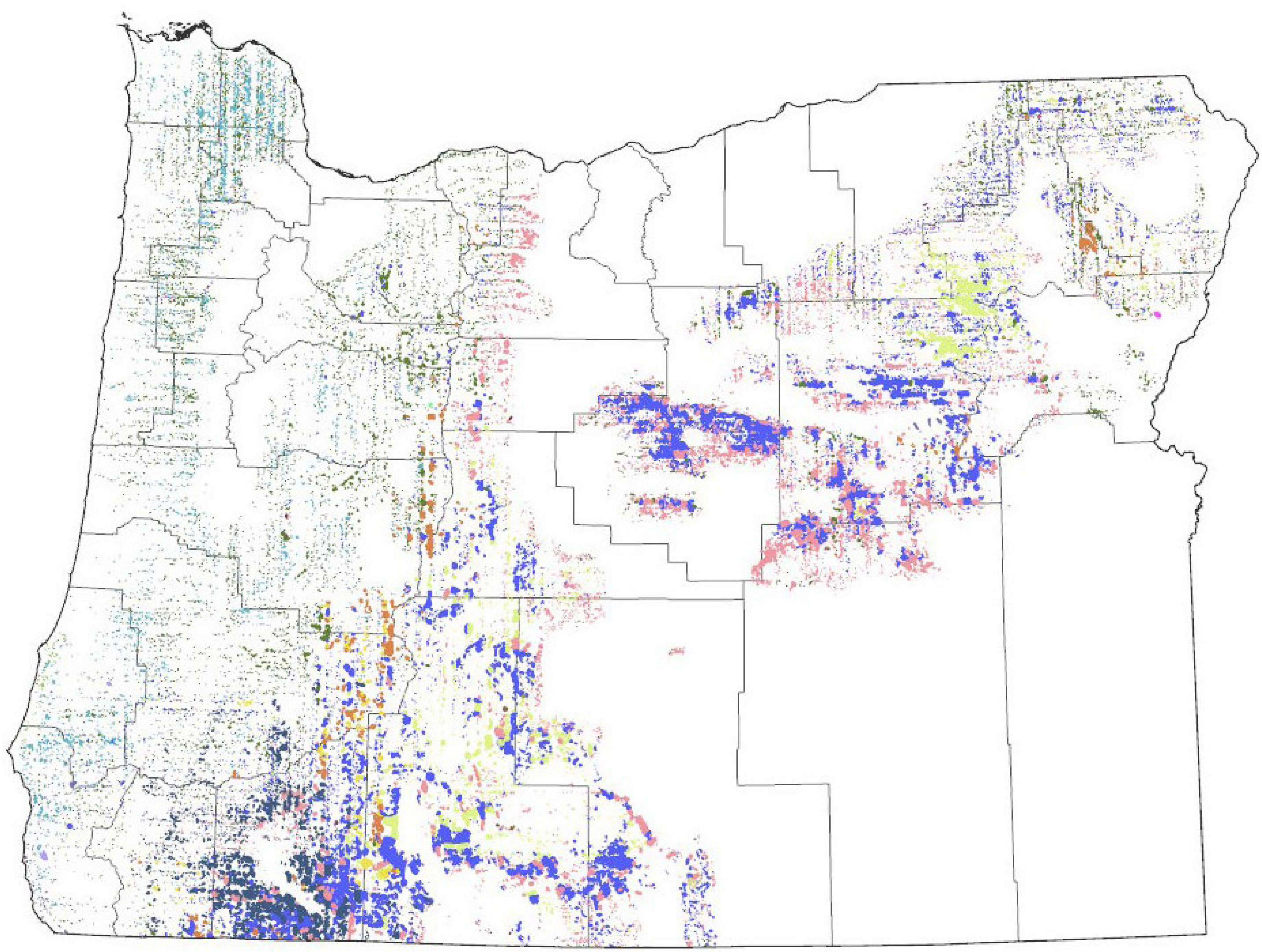


Figure 7. Map of tree damage and mortality as mapped by the 2023 general aerial survey. The largest contributors to damage and mortality are shown in the legend above. Often, tree mortality is a result of a complex of multiple different agents, starting with the most damaging and followed by less damaging agents that can only attack when tree defenses become exhausted. In recent years drought stress has caused the majority of initial tree damage which allowed opportunistic insects to finish trees off. Perimeters enhanced for visibility.

Mortality was observed in 2.26 million acres and damage (defoliation, flagging) in 140,000 acres across the 37 million acres covered by surveys. The visual signature for recently dead trees is a red or brown crown which is easier to see than the signature of a thinning crown in a damaged tree; therefore, mortality is often easier than damage to comprehensively capture. Most of our pests cause swift, direct tree mortality rather than damaging trees by consuming leaves or causing premature leaf drop.

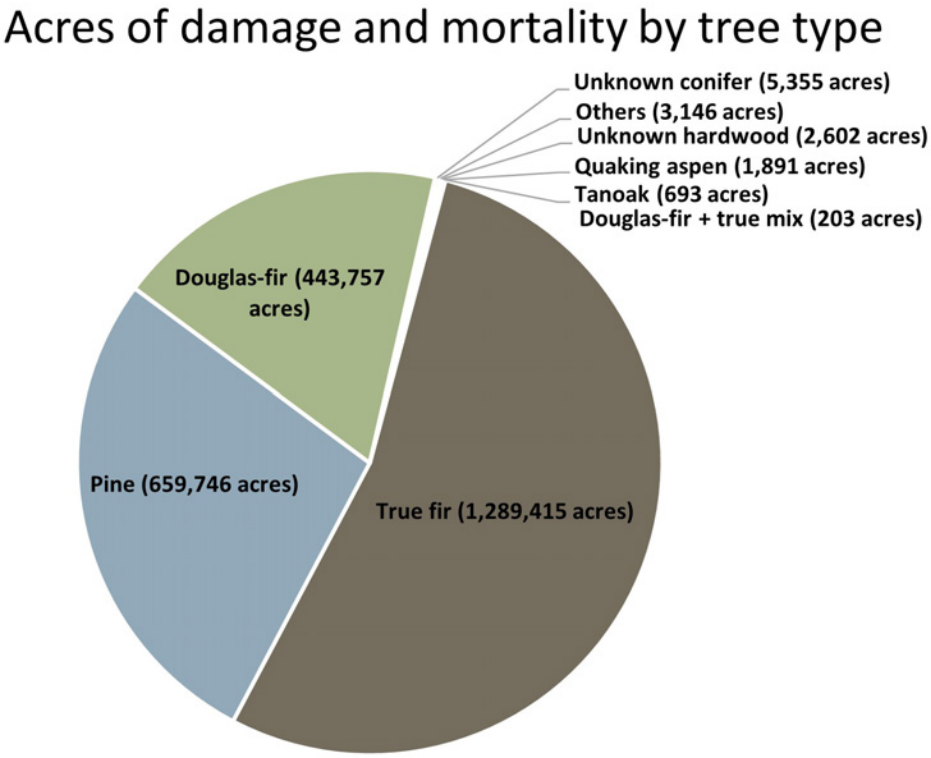


Figure 8. Proportion of damage and mortality by tree type as observed in 2023 aerial surveys.

The majority of the tree damage and mortality observed in 2023 occurred in Oregon's seven true fir species (genus *Abies*): grand, white, noble, Pacific silver, California red, and subalpine fir (Fig. 8). In 2022 we observed historic levels of true fir mortality due to widespread drought, underlying root diseases, and subsequent attack from fir engraver bark beetles. Some of these fir were growing outside of their preferred habitat due to wildfire suppression and ongoing hot droughts eventually pushed them out of this fringe habitat. Despite another year of extremely high levels of true fir dieback in 2023 we saw a slight decrease in true fir mortality relative to 2022.

The next highest affected group of trees was pine (genus *Pinus*), of which there are eight species in Oregon: ponderosa, lodgepole, Jeffrey, western white, sugar, knobcone, limber, and whitebark. Notable varieties include: the eastside subspecies of ponderosa (*P. ponderosa* ssp. *ponderosa*) which tolerates more xeric conditions than its relative Willamette Valley pine (*P. ponderosa* ssp. *benthamiana*) which grows west of the Cascade crest, and the broadly distributed lodgepole pine (*P. contorta* ssp. *latifolia*) which tolerates xeric conditions and requires fire for seed release relative to shore pine (*P. contorta* ssp. contorta) which exhibits a slightly different growth form and thrives along the coast. Ponderosa pine suffered the majority of observed damage and mortality followed by lodgepole pine. Several species of pine-infesting bark beetles attack various varieties of pine when they are overstocked and outcompeting each other for resources.

Douglas-fir (*Pseudotsuga menziesii*), one of our most valued timber species, was the third most impacted tree type. This single species occurs as coastal Douglas-fir (var. *menziesii*) throughout much of the state and as a separate variety, Rocky Mountain Douglas-fir (var. *glauca*) in parts of eastern Oregon. The cause of mortality in this species ranges from direct impacts from drought or storm damage, both of which may be followed by opportunistic attacks from Douglas-fir beetle, Douglas-fir engraver, and, increasingly, flatheaded fir borer.

The remainder of observed damage occurred at much lower levels in various other species of conifers and hardwoods.

SURVEYS, MONITORING AND OTHER PROJECTS

Aerial Detection Survey (ADS)

The Oregon (and Washington) cooperative aerial survey program between state (Oregon Department of Forestry, Washington Department of Natural Resources) and federal forestry (US Forest Service) is an annual effort and the longest recorded statewide forest survey in the nation (Est. 1947). All forested parts of the state are flown annually to quantify tree damage and mortality from insects, diseases, and abiotic stressors (e.g., weather, climate, natural disasters). This survey is the most cost-effective method to provide statewide monitoring of conditions and to detect emerging issues.

Figure 9. Ponderosa pine mortality observed over the Ochocos in 2023 (Christine Buhl, ODF).

There are some caveats to the aerial survey data shown in our tables, figures, and maps, and we advise working with ODF or USFS aerial survey programs to accurately interpret our data. Data obtained via aerial survey are not comprehensive but can provide a long-term, watershed-scale overview of trends across Oregon. Not all damage can be observed by this survey due to lack of visibility or timing. For example, damage from root diseases is typically not visible from the air and is underrepresented in survey data. Often, a complex of agents is present rather than the single agent marked in the surveys. For example, mortality of some tree species is marked as beetle damage, despite drought often acting as the underlying or primary causal agent.

Aerial surveys are conducted by two observers that look 1-2 miles out from their side of fixed-wing aircraft (Fig. 9), and record on a computer tablet the amount of damage and suspected causal agent (Fig. 10). A statewide "general" forest health survey that covers roughly 28 million acres is flown each year. Additional "specialty" surveys, are flown as needed using fixed-wing or helicopter aircraft to capture damage agents, such as Swiss needle cast (SNC) or sudden oak death (SOD), that may not appear during the course of the general survey or require a closer look. With these additional surveys, the agencies cover a total of 35 to 41 million acres each year. View aerial survey in action: https://youtu.be/XPrKjWaoeeA

The 2023 general survey covered 37 million acres. Smaller SOD flights revisited areas of southwest Oregon. SNC is flown on even years and will resume in 2024. Aerial observers recorded 2.4 million acres of total damage and mortality from insects, disease (excluding Swiss needle cast), animals, and abiotic (non-wildfire) agents. Another 200,000 acres of wildfire damage and mortality were reported by the Northwest Interagency Coordination Center (NWICC) (Figs. 5, 6, and 11). Wildfire damage from current year fires across all ownerships is captured more comprehensively by the NWICC. Additional data are obtained by using ground inspections, traps, drones, and remote sensing.

Figure 10. Tree mortality (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).

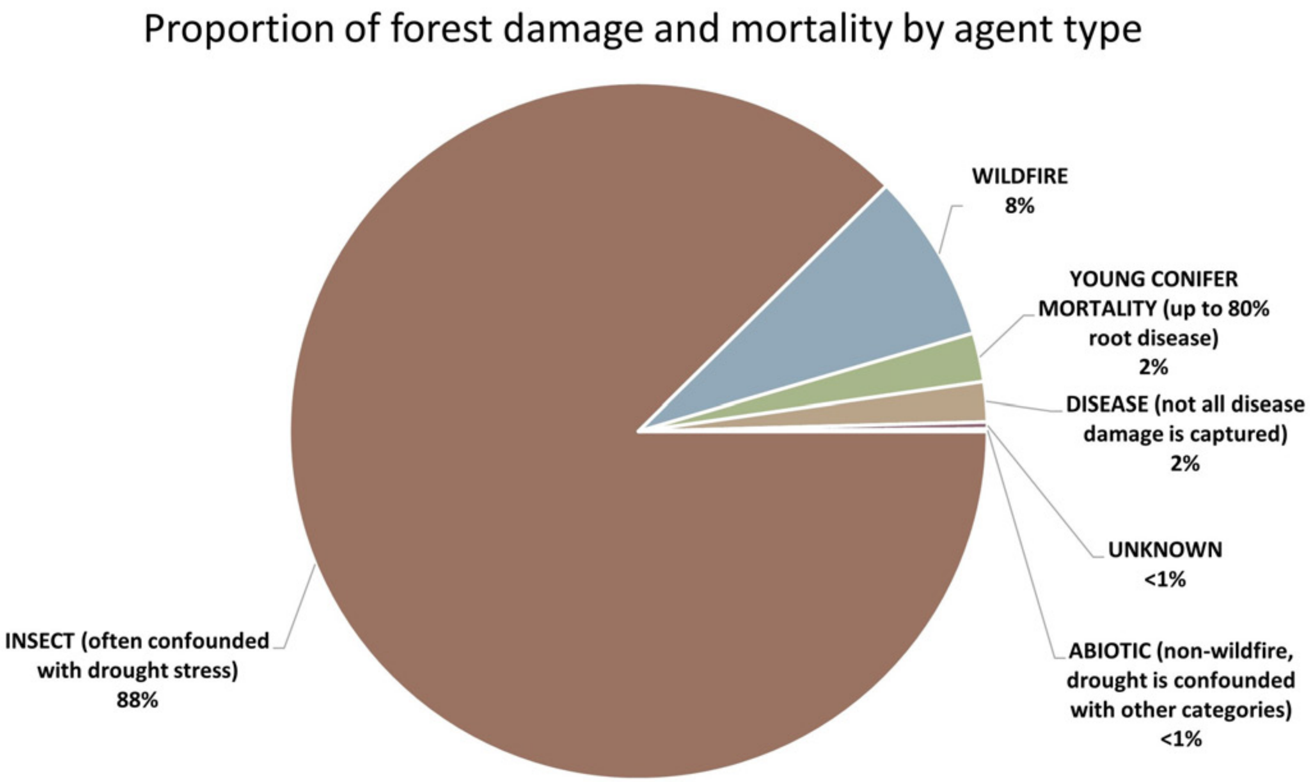


Figure 11. Proportion of forest damage and mortality by agent as observed in 2023 aerial surveys.

ADS resources:

- ADS data and maps for all years: https://tinyurl.com/FHAerialSurvey
- ADS 2023 Storymap of results: https://usfs.maps.arcgis.com/apps/mapviewer/index.html?webmap=6c8f8b7ae79e422188683b0b93aac833

SURVEYS, MONITORING AND OTHER PROJECTS

Hazard Tree program
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 (Fig. 12), pine slash management, and anti-aggregation pheromones. These funds are applied on federal lands, and also applied to non-federal lands through ODF as a cost share. In 2023, USFS applied bark beetle mitigation treatments on 1,584 acres of federal lands and non-federal landowners applied treatment on 21 acres on 4 ownerships. The program will be undergoing revisions in 2024, which are expected to minimize the proportion of costs for the landowner. Apply for cost share funds on non-federal lands through ODF: https://tinyurl.com/ODFcostshare

Figure 12. Unthinned stand to the left of a cost share thinning project to the right. Thinning reduces competition for moisture which allows for increased tree growth (Christine Buhl, ODF).

Douglas-fir tussock moth (DFTM) trapping program
This ongoing monitoring trap system (Est. 1979) detects increases in DFTM moth numbers and can predict building outbreaks or determine status of current outbreaks in eastern Oregon (Pg. 22).

Educational Opportunities
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, in-person seminars, and field trainings, 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 (Pg. 23) was developed and presented in Grants Pass. 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 observe samples, test their knowledge on signs and symptoms of specific exotic invasive species, and have Q&A dialogue with technical experts.

Forest health education resources from ODF, USFS, and OSU forest health programs:

- ODF Forest Health: http://tinyurl.com/odf-foresthealth
- USFS Forest Health Protection: https://www.fs.usda.gov/detail/r6/forest-grasslandhealth/insects-diseases/?cid=stelprdb5300513
- 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 insect and disease information (ODF): http://tinyurl.com/odf-foresthealth or QR code

Forest pollinator projects

Most insects provide beneficial ecosystem services in the background and go unnoticed until their populations decline. These services include pollination, decomposition, pest control, and other components of nutrient cycling. Insects such as predacious beetles and parasitic wasps keep populations of forest pests such as scale insects and woodboring beetles at manageable levels. Pollinators are common in forests, and provide a critical ecosystem function for flowering plant reproduction. In turn, forests provide the necessary habitat and resources to maintain pollinator populations, such as flowering plants for nectar, coarse woody debris for overwintering, and undisturbed soil for ground nesting (Fig. 13). Task forces such as the Oregon Bee Project work to increase our understanding of these beneficial insects and contribute to efforts to enhance habitat, produce research, and spread information on how to encourage these insects. Ways to broadly enhance habitat for beneficial insects include: creating "skip zones" where pesticides are not applied, addition of pollinator plants in and along stands (e.g., along roadsides and embankments, skid trails and old landings where soil is too compacted for trees), and avoidance of sanitizing sites by removing understory plants and course woody debris that do not increase pest or wildfire risks.

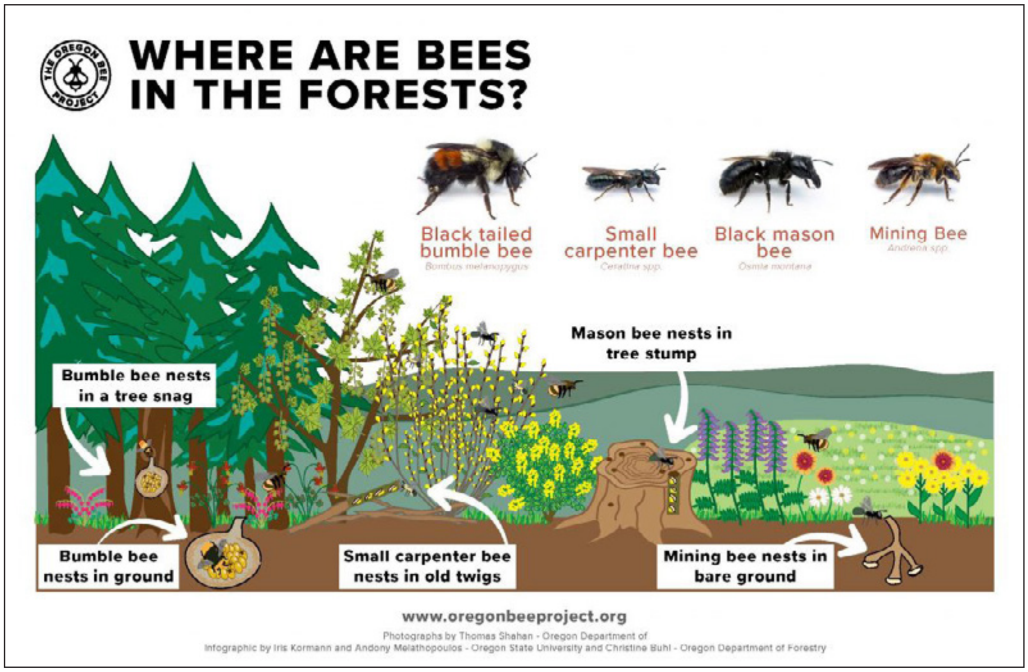


Figure 13. Oregon Bee Project forest bee outreach postcard.

Pollinator resources:

- **NEW!** Information on bees in forests: https://site.oregonforests.org/media/2185
- Information on bees in forests: https://woodlandfishandwildlife.com/ publications/insect/forest-bee-pollinators
- Videos on enhancing pollinators in your forest: https://extension.oregonstate.edu/collection/bees-woods
- Dedicate pollinator habitat on zoned timber land: https://www.oregonlaws.org/ors/527.678
- Oregon Bee Project: https://www.oregonbeeproject.org/forest

ABIOTIC AGENTS: CLIMATE & DROUGHT

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 can repel, trap, and drown insects. Pitch can also seal off wounds to prevent infestation by pathogens that cause diseases; furthermore, 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 hot 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. In the Pacific Northwest, the latest bout of peak drought began in 2020. And there are natural, larger-scale alternating periods of cooling and warming (glacial versus interglacial periods), and currently earth is in a warmer phase. There are also Pacific Decadal Oscillations termed El Niño (warm phase) and La Niña (cool phase) which are periodic fluctuations in sea surface temperatures and overlying atmosphere that can alter climate, typically for a period of two years.

2023 was the final year of La Niña which, in this region, causes cooler and wetter winters. We started the year out with these cooler, and wetter conditions but they were variable across the state and tapered off later in the year, resulting in drought across 50% of the state. We experienced moisture recovery from La Niña in southeastern and parts of central Oregon. The coast range and Willamette Valley experienced far less moisture recovery. Snowpack across the state reached 154% of the 30-year normal due to a return to normal winter precipitation and temperatures; although, temperatures suddenly increased mid-April, resulting in early snow melt. Despite periodic rain and snow events during the course of the water year (October 2022 - September 2023), we received 2.5 inches less precipitation than our 30-year normal, and it was the 40th driest year out of the last 128 years. Rather than heatwave events, we experienced consistently warm days starting around July and into October, particularly in western Oregon. Eugene, Portland, Salem, and Redmond each recorded around 100 days of >80°F temperatures and 2023 ranked as the warmest year on average for those areas.

We entered an El Niño phase heading into winter 2023-2024, which typically results in warmer average conditions and variable precipitation, but generally less precipitation in the form of snow. Globally, we've seen a 2.7% decline in annual snowfall since 1973. If we follow one of the higher risk trajectory scenarios for global warming, we could see a 30% decline in annual snowfall in the lower 48 states by 2100. Low precipitation is only one half of the drought equation. The drying effect from warmer temperatures exacerbates deficiencies in precipitation (evaporative demand). Summers in the Pacific Northwest have been warmer on average over the past 10 years. Site variables that expose trees to more drying or less water-retention result in intensified drought conditions. These variables include slope, aspect, soil type, wind and sun exposure, etc., and should be factored into what species are planted where in a region and within a site.

Predictions for 2024 are up to an 80% chance of a strong El Niño phase, in which we may experience cooler stretches but the overall average temperature will be higher than normal and snowpack lower or of shorter duration. The far northwestern corner of the state is predicted to experience higher temperatures starting around March, but then decreasing around April; although, the northern strip of the state is predicted to experience higher levels of drought starting around May. Precipitation outlooks are lowest for northeastern Oregon starting around February and expanding along the northern strip of the state around March.

Microclimate due to site factors 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 (Fig. 14).

Figure 14. Western redcedar (left), Douglas-fir (center), grand fir (right) with common symptoms of drought stress such as crown thinning and topkill. These species range from low to moderate in their tolerance to drought and have been early indicators of drought stress across the forested landscape (Christine Buhl, ODF).

Changing climatic 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 (e.g., winter).
2. Short droughts can be tolerated by some species that have evolved the ability to reduce water loss through leaves. This strategy limits photosynthesis and is not successful for prolonged periods of drought.
3. If there are sequential years of drought and trees don't get a sufficient reprieve to rebuild damaged tissues, they may never catch up even if a drought period is punctuated by adequate precipitation.
4. Sudden changes in heat or precipitation can shock trees even if changes are moderate.

Climate change and drought resources:

- Oregon Water Resources Department's monthly drought summary email: https://tinyurl.com/drought-report-email
- Overview of drought impacts on trees: https://sflonews.wordpress.com/2021/08/12/drought-and-tree-mortality-in-washingtons-conifers/
- Drought impacts on forests and pests: https://youtu.be/wHZ1G5wH4r8
- ODF Drought fact sheet: https://www.oregon.gov/odf/Documents/forestbenefits/Drought.pdf
- Oregon Climate Change Assessment: https://blogs.oregonstate.edu/occri/ oregon-climate-assessments
- Climate assessment forest impacts: https://nca2023.globalchange.gov/chapter/7/

ABIOTIC AGENTS: CLIMATE & DROUGHT

Recent mass-mortality of specific tree species has been an alarming sight across the Pacific Northwest landscape (Fig. 15, http://tinyurl.com/cc-pnw-demise). Dieback has been especially apparent in Douglas-fir, western redcedar, true fir, and bigleaf maple in areas where they seemed to be thriving or at least inhabiting for many years. A key unifying theme in dieback has been direct stress from ongoing and intense hot drought conditions brought on by climate change. In 2021, agencies in the Pacific Northwest began mapping western redcedar dieback that had been noticeable for at least a decade. This dieback often occurs in areas where western redcedar should thrive such as shaded stands along streams. Even in those habitats, moisture levels have been dropping which was directly correlated with reduced growth rates and subsequent mortality (https://tinyurl.com/WRCStorymap & https://www.biorxiv.org/content/10.1101/2023.01.11.522134v1.full). In 2022, our aerial survey program detected a historic level (over 1 million acres) of true fir dieback in areas where fire suppression had allowed true fir to grow outside of its range or where drought conditions altered the suitability of the site for these less drought-tolerant species (https://www.theguardian.com/us-news/2022/dec/15/oregon-dead-fir-trees-conifers-climate-crisis). And although the 2021 scorch event was not solely brought on by climate change it was thought to be exacerbated by it (https://www.climatehubs.usda.gov/hubs/northwest/topic/2021-northwest-heat-dome-causes-impacts-and-future-outlook).

Figure 15. Climate change-influenced damage and dieback in (clockwise from top left): true fir (Danny DePinte, USFS), western redcedar (Nicholas Harris), Douglas-fir (Danny DePinte, USFS), and bigleaf maple (Christine Buhl, ODF).

MANAGING FOR RESILIENCE

The most appropriate actions to improve tree resilience against climate change, wildfire, insect pests, and some diseases often employ the same strategies because they target tree and stand health. Forest resilience best management practices are:

1) Plant the right tree in the right place and account for microclimate and projected climate change (Fig. 16).
- Know tree species growth requirements and common pests (https://plants.usda.gov/home)
- Plant within a species' range rather than along the edge (https://usfs.maps.arcgis.com/apps/webappviewer/index.html?id=4ebf103ddeeb4766a72e58cb786d3ee2)
- Determine where species will thrive under projected climate scenarios (https://seedlotselectiontool.org/sst/)
- Be aware of the influence of soil type, aspect, slope, sun and wind exposure, etc. may have on the microclimate of a planting site (https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx | https://usfs.maps.arcgis.com/home/item.html?id=b75880ad0d59465591c75f7ffdc42f19)

2) Establish trees well so that root systems develop to their fullest potential (https://www.oregon.gov/odf/Documents/workingforests/reforestationguide.pdf)

3) Maintain stocking levels appropriate for the species that can be supported by current and future moisture levels.
- Optimal species stocking levels (https://catalog.extension.oregonstate.edu/em9206/html)
- Temperature and precipitation status, trends, and projections (https://tinyurl.com/drought-report-email)

4) Prevent damage from abiotic and biotic stressors and remove stressed and damaged trees to allow more resources for healthier trees.

5) Encourage stand diversity (e.g., species, age, patchiness) and natural ecosystem processes.

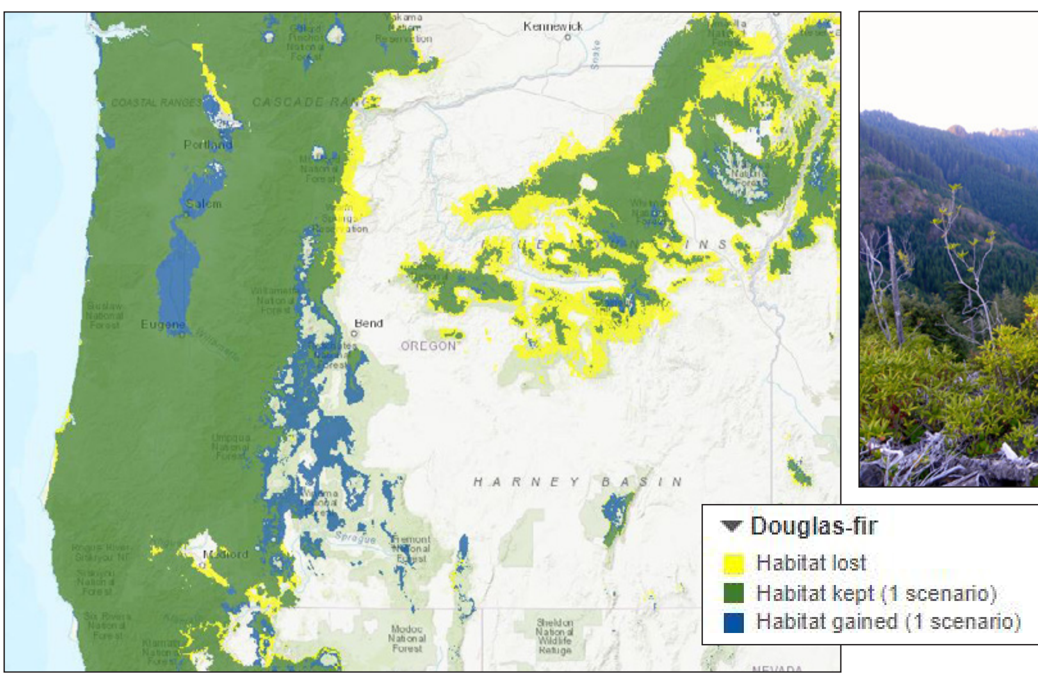


Figure 16. Projected range under a conservative climate scenario for Douglas-fir trees derived from 1961-1990 seedlot conditions that are predicted to endure 2011-2040 conditions (left, https://specieshabitattool.org/spht/), right Douglas-fir dominated managed stand (Christine Buhl, ODF).

ABIOTIC AGENTS: WILDFIRE

Wildfire

Cooler and wetter conditions from our last year of La Niña began to taper off as we entered an El Niño cycle and warmer conditions increased by spring 2023. By midsummer, warmer and drier conditions increased drought ratings in many Oregon counties particularly from the Cascades toward the coast. Pulses of heat in mid-May and again the beginning of June preceded several fires in the northern half of the state. Later in the summer, fire activity in the Pacific Northwest reached normal to below normal levels and wildfire personnel assisted Canada, which experienced a historic wildfire season resulting in about 45 million acres of damage.

Figure 17. Alder Creek Fire (Moriah Watson, ODF).

In Oregon, approximately 206,000 acres were damaged by wildfire (Figs. 17 and 18), which was 65% lower than the 10-year average and 54% lower than in 2022 (Fig. 19). The total number of fires was 8% lower than the 10-year average. The acres of fire damage as a result of humans versus lightning was similar; although, the number of fires from human activity was three times higher than from lightning.

The largest fires (Fig. 20 fire map) included the 34,000-acre Flat Fire (human-caused) and 22,000-acre Anvil Fire (under investigation) in Coos county, 31,000-acre Bedrock Fire (under investigation) and 25,000-acre Lookout Fire (lightning) in Lane county, and 17,000-acre Hat Rock Fire (under investigation) in Umatilla county. The Smith River Complex burned 95,000 acres as a result of lightning mostly in California but did reach parts of Curry and Josephine counties in Oregon.

Figure 18. Lookout Fire at McKenzie Bridge (Payton Bruni, ODF).

Initial attack efforts such as early detection continue to aid in catching fires quickly to keep them small. Aerial heat detection using a Forward Looking InfraRed (FLIR) camera resulted in 33 first detections and confirmed another 7 detections that were reported as ground crews were en route. 32 of these 33 new fires were found when fire danger levels were at "Extreme" (the other found during spring FLIR training) and the majority of the fires were found on federal land interspersed with other ownerships that ODF protects. A major improvement to the program in 2023 was the installation of a Starlink antennae for better internet connectivity during flights to provide ground crews with information such as live-streaming fire details like fire geometries, images, and video.

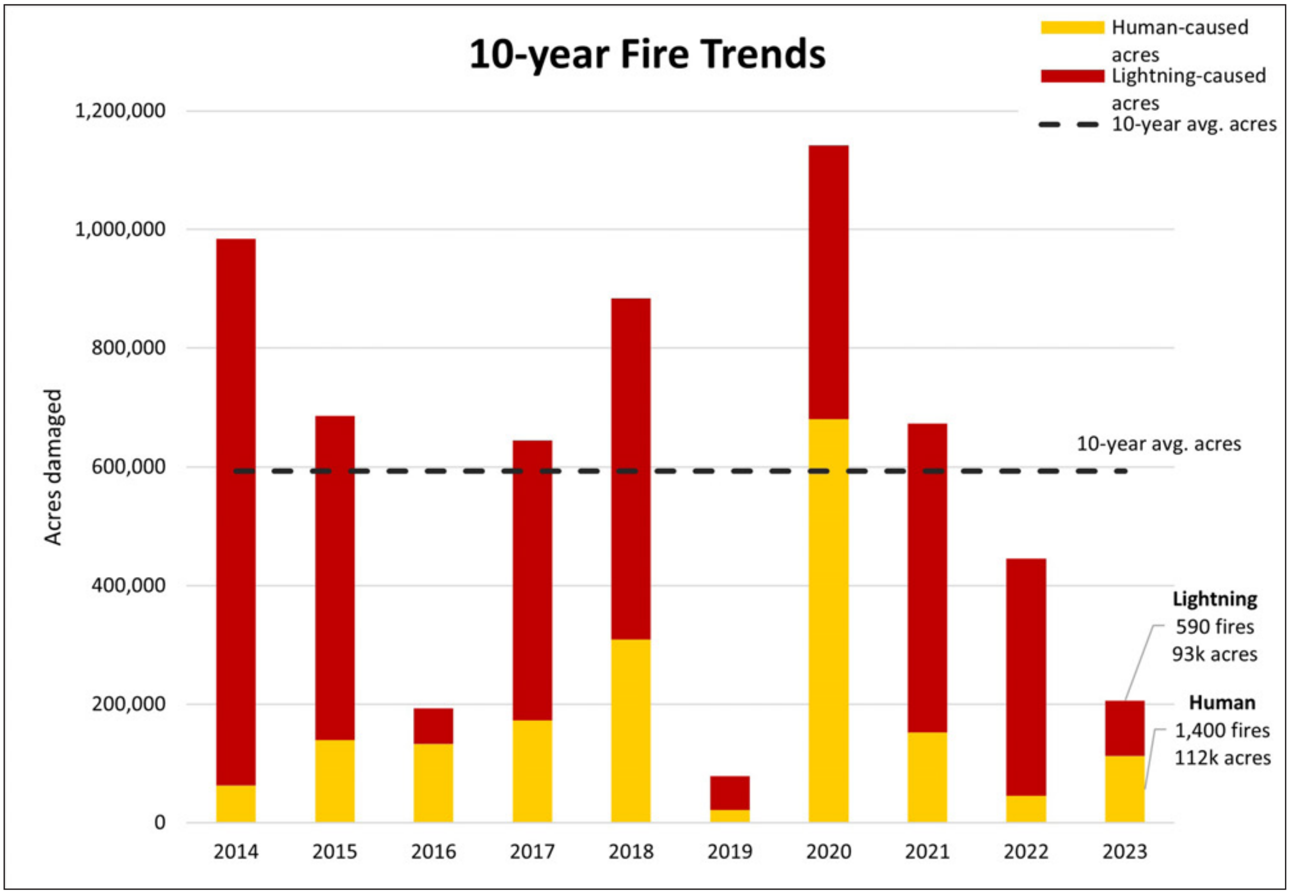


Figure 19. Oregon 10-year statewide wildfire trends across all ownerships and all protection districts (USFS, BLM, ODF, tribal, etc.). Wildfire data from the Northwest Interagency Coordination Center.

ODF, in collaboration with state and federal partners, has launched the 20-Year Landscape Resiliency Strategy (https://www.oregon.gov.odf/pages/20-year-strategy.aspx), a crucial initiative designed to strengthen Oregon's natural landscapes against the growing challenges of wildfires. Targeting approximately 13.1 million acres of diverse ecosystems such as forests and rangelands, this strategy aims to enhance ecological resilience and modify wildfire dynamics. The approach involves comprehensive on-the-ground resilience treatments like thinning, prescribed burns, invasive species removal, and innovative post-fire restoration practices. These efforts are geared towards fostering landscapes capable of enduring extreme fire, drought, and pests, while also catalyzing economic development through biomass utilization. Integral to this strategy is rigorous monitoring, data collection, and adaptive management for continuous refinement of these efforts.

Wildfire resour es:

- 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
- Post-fire research conducted across Oregon agencies: https://www.fs.usda.gov/research/pnw/products/dataandtools/datasets/postfire-catalog-research-and-monitoring-projects-after-2020

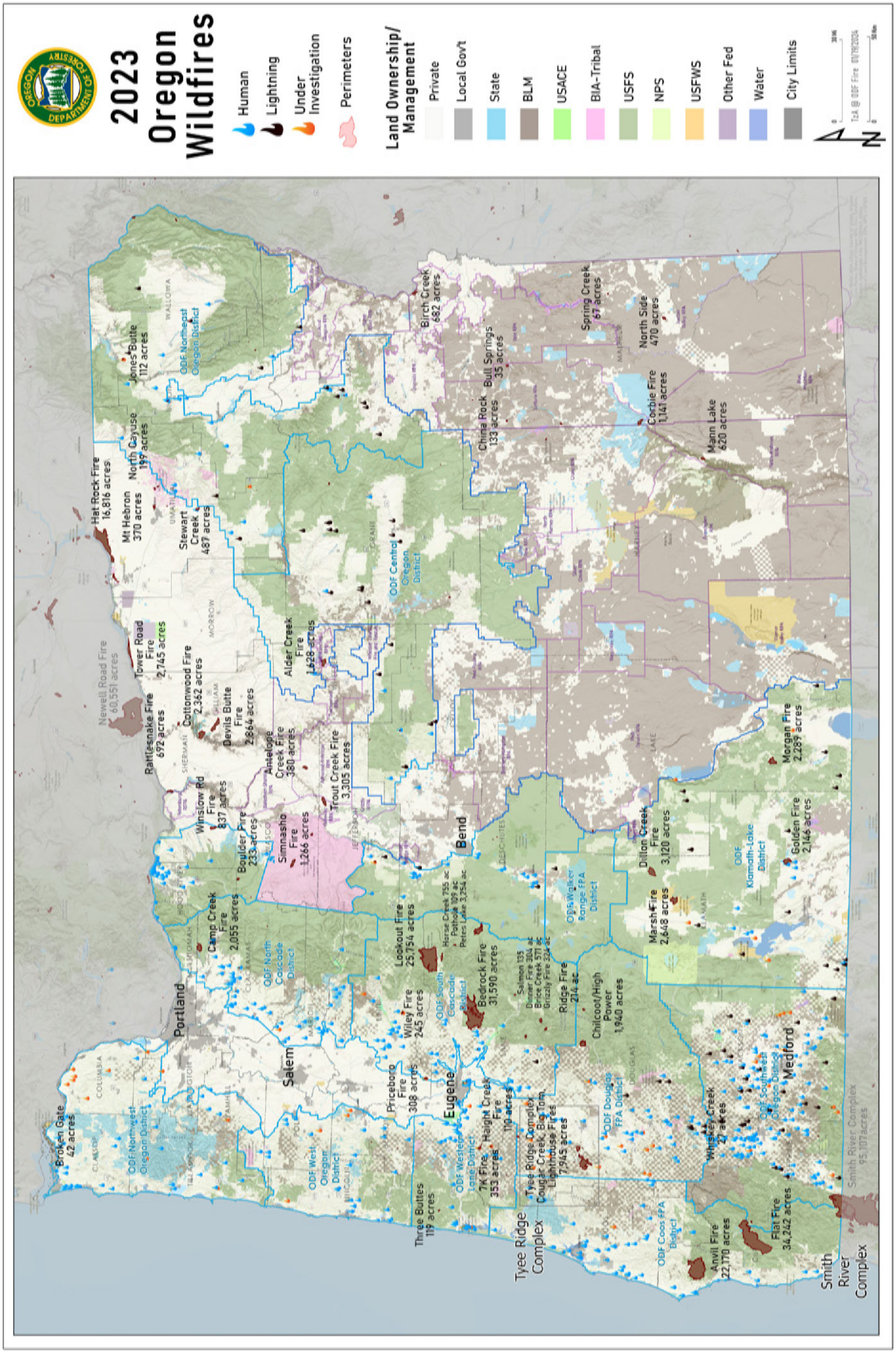


Figure 20. Map of statewide wildfires in 2023 (Teresa "TzA" Alcock, ODF).

FIRE x FOREST INSECTS

Insect activity often ramps up following wildfires; although, the majority of studies indicate that excess tree mortality from insect outbreaks doesn't necessarily result in increased fire risk. Beetle-killed trees that retain red, dry needles are highly flammable but, once needles have dropped, these bare trees are less flammable than green trees. Trees species such as true fir retain their red needles for longer, which may extend their risk of increased flammability. Trees such as pine that exude pitch tubes when attacked by bark beetles may present increased risk of fire laddering up a trunk dotted with flammable pitch.

Trees that survive a fire, but are damaged, have weakened defenses and release chemicals that are attractive to insects. In Oregon, insects such as bark beetles and flatheaded fir borer can attack and kill these trees that are still alive if the phloem layer is not too damaged. They reside just under the bark and do not tunnel into the wood. These tree-killing insects typically infest within the immediate few years following fire. Their populations can build in fire-damaged and otherwise stressed trees and spill over and overwhelm the defenses of healthy trees, resulting in an outbreak. Many of these insects are native, widespread, and part of a healthy ecosystem when their numbers are at normal levels. Most of our native woodboring insects do not typically kill trees, but can infest the severely damaged and dying trees (Fig. 21), and, as the name suggests, tunnel into wood which results in timber defect. These woodboring insects include various roundheaded, flatheaded, and ambrosia beetles, and woodboring wasps: https://www.oregon.gov/odf/Documents/forestbenefits/Woodboringbeetles.pdf

Post-fire forest health est management practices:

1. Focus restoration efforts on the least damaged or most resilient stands. Focus salvage and replant efforts on the more damaged stands.
2. Remove fire-damaged trees that are still alive, and any other trees showing signs of stress, to reduce reservoirs for pest outbreaks that may spill over into healthy trees. Identify and remove trees with levels of crown scorch and/or bole char that may result in mortality or insect attack: (summary guide) https://tinyurl.com/ODFpostfire | (full guide) https://tinyurl.com/postfireguide
3. Remove and process merchantable salvage timber within the year, or as soon as possible, to reduce defect from woodboring insects and fungi.
4. Treat fire-damaged stands of >10" DBH Douglas-fir with MCH repellent the March after a wildfire, to prevent population buildup of Douglas-fir bark beetle in live, fire-damaged trees: https://www.oregon.gov/odf/Documents/forestbenefits/mch-for-douglas-fir-beetle.pdf
5. Destroy pine slash (3-8" diameter) before April Ips beetle flights, or within 2 months of slash creation: https://www.oregon.gov/odf/Documents/forestbenefits/Slashmanagement.pdf
6. Replant with seedlots appropriate for future climate predictions (Pg. 15).
7. Incorporate diversity in tree species, age, size, spacing, and stand patchiness wherever possible.
8. Consider implementing conservation strategies during post-fire restoration efforts, such as: adding pollinator plants to erosion control seed mixes; replanting riparian areas with the same pre-fire tree communities that support terrestrial and aquatic communities; and allowing growth of non-invasive plants as refugia for natural enemies in the understory, along roadsides, and around leave trees. During clearcuts, consider leaving clusters of leave trees that are skipped during herbicide treatments to create pockets of wildlife habitat.

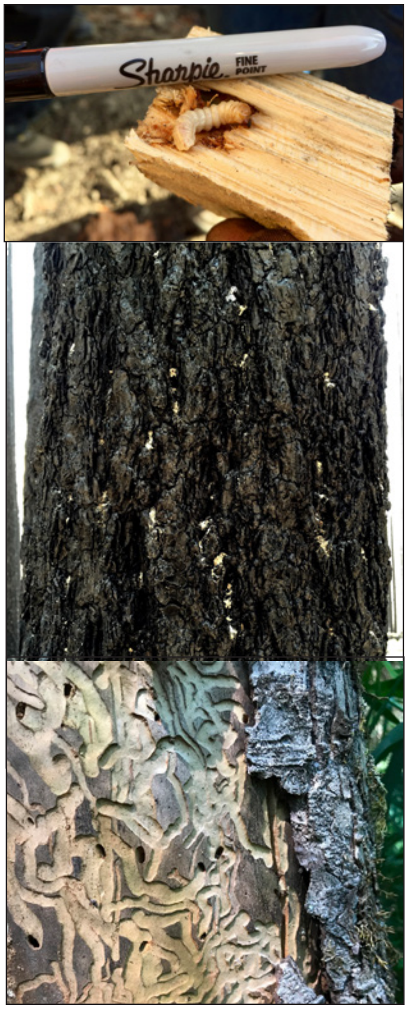


Figure 21. Woodboring beetle larvae (top) cause defect and can even be heard chewing during or immediately after fire damage. Indicators of woodborer activity include: pale boring dust in bark crevices (middle) and feeding galleries and round or oval holes in wood (bottom) (Christine Buhl).

FOREST INSECTS

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 the additional resources that producing defenses require. 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, 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
- Landowners may apply for beetle cost share funds (Pg. 10) through ODF stewardship foresters (Pg. 1) for bark beetle prevention and mitigation treatments such as thinning, pine slash management, and anti-aggregation pheromones (https://tinyurl.com/ODFcostshare).

Bark beetles are the most common opportunistic pests of trees on our forested landscape. We have only a few species that can kill trees and they are native and widespread. Despite their small size (about the size of a grain of rice), it's only when their numbers explode that they cause mass-tree mortality by overwhelming tree defenses. Bark beetles burrow just under the bark (they do not enter wood) which girdles trees by cutting off vascular tissues that are important for transporting water and nutrients.

Figure 22. Fir engraver damage includes topkill (top) and horizontal galleries (bottom) (Christine Buhl, ODF).

In recent years the majority of tree damage and mortality has been detected in "true firs" (*Abies* spp.). The primary causes include chronic hot droughts, root disease, balsam woolly adelgid, and opportunistic attack by fir engraver beetles (*Scolytus ventralis*). Many of these sites are becoming marginal for fir 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 stressors and primary causes of tree mortality in true firs are drought and root disease.

Signs and symptoms of fir engraver bark beetles (Fig. 22) typically include dieback in the top third of the crown, which later extends to the full crown. Fir engraver galleries cause a separation between the wood and bark, which often sloughs off revealing the distinctive horizontal galleries in sapwood. Extensive fir engraver attacks indicate that the conditions or the site may no longer be hospitable for the species or seedlot of true fir present. Root disease may also be present at the site. Management is situation-specific but should address drought, root disease, and any other underlying factors rather than be directed at the beetle itself. Fir engraver info: https://www.oregon.gov/odf/Documents/forestbenefits/FirEngraverBeetle.pdf

In Douglas-fir (*Pseudotsuga menziesii*) the most common attacking insects that can cause mortality are Douglas-fir beetle (DFB, *Dendroctonus pseudotsugae*) and flatheaded fir borer (FFB, *Phaenops drummondi* prev. *Melanophila*). Douglas-fir bark beetle is opportunistic on trees damaged by storms, often preying on blowdown first, or trees damaged by drought, root disease, or wildfire. Removal of blowdown, damaged, and diseased trees, and reducing stand density goes a long way toward increasing resilience against this insect. Further protection is gained by applying MCH, a repellent pheromone that is stapled to trees in a grid pattern across the landscape. MCH reduces or distributes concentrations of this insect in an area so their populations cannot overwhelm the defenses of healthier trees. Evidence of this insect includes piles of brown boring dust (frass) in Douglas-fir bark crevices; and long, vertical, branched galleries under the bark (Fig. 23).

Figure 23. Douglas-fir beetle damage includes brown boring dust in bark crevices (top) and long vertical galleries (bottom) (Christine Buhl, ODF and Kenneth E. Gibson, USFS).

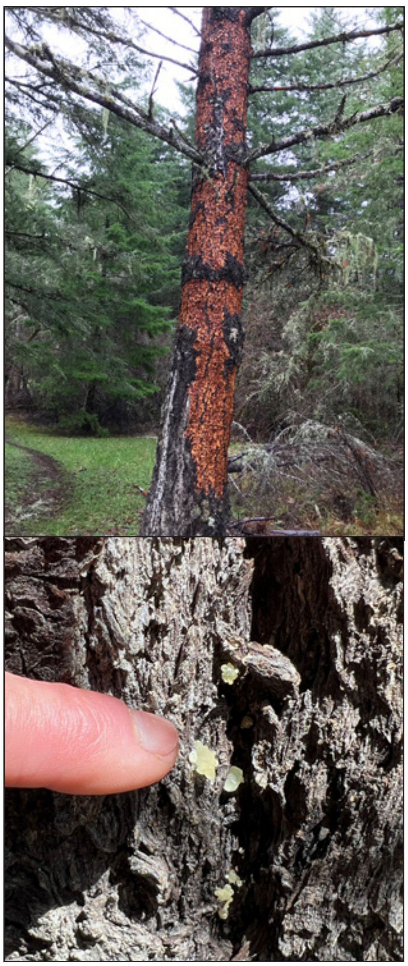


Figure 24. Flatheaded fir borer damage results in woodpeckers flaking off bark (top) and pitch pearls (bottom) (Dan Menk, Christine Buhl, ODF).

Flatheaded fir borer is a woodboring type of beetle. It behaves like a bark beetle in that it girdles trees just beneath the bark but does not enter the wood. This insect is native and widespread. It is becoming more of a problem on landscapes that are becoming fringe habitat for populations of Douglas-fir due to the stress of intensifying droughts. Common signs of flatheaded fir borer (Fig. 24) include branch flagging and bark flaked off by woodpeckers as they search for larvae that are present within the bark. When inspecting Douglas-fir with flaked off bark, other visible signs include pitch droplets ("pearls") and 1/8-1/4 inch oval holes, from entrance and exit of the insect, respectively. Extensive damage from flatheaded fir borer indicates that the site quality may be poor, aspects of the site may be affecting microclimate, or drought conditions are too high to support Douglas-fir. Both Douglas-fir beetle and flatheaded fir borer may be active at high stress sites, be aware that MCH does not work against flatheaded fir borer and it may only be a temporary solution if stressed trees remain on the site.

In pine, there are three beetles that may cause mortality, depending on the tree species. **Western pine beetle** attacks only ponderosa pine, and may be evident from the presence of pitch tubes and puzzle pieces of bark flaked off by woodpeckers in search of grubs (Fig. 25). In all of our pine species **mountain pine beetle** and **Ips beetles** may attack. The former leave behind pitch tubes and the latter cause dieback in the top third of crowns. For all of these insects it is important to reduce overcrowding and competition around pine, and remove stressed trees. Historically, mountain pine beetle has killed pines across millions of acres in the west. In Oregon, overly dense stands of lodgepole that spring up due to fire suppression and lack of thinning, are particularly inviting for beetle outbreaks.

FOREST INSECTS

Figure 25. Indicators of pine-attacking bark beetles include: woodpeckers flaking off bark in ponderosa attacked by western pine beetle (left), pitch tubes (center), topkill from Ips beetles (right) (Christine Buhl, ODF).

Sap-sucking and defoliating insects also impact trees on our landscape by causing damage and sometimes direct or indirect mortality. **Balsam woolly adelgid** (BWA, *Adelges piceae*) is an invasive, but established, and chronic sap-sucking pest that has long been killing true firs in Oregon (Fig. 26). Control or sanitation is particularly difficult for firs at higher elevations. True firs are already suffering an increasing amount of mortality due to droughts and fir engraver attack. **Douglas-fir tussock moth** (*Orgyia pseudotsugata*) populations in Douglas-fir and true fir are continuing to subside as indicated by trapping efforts (Fig. 27) in eastern Oregon.

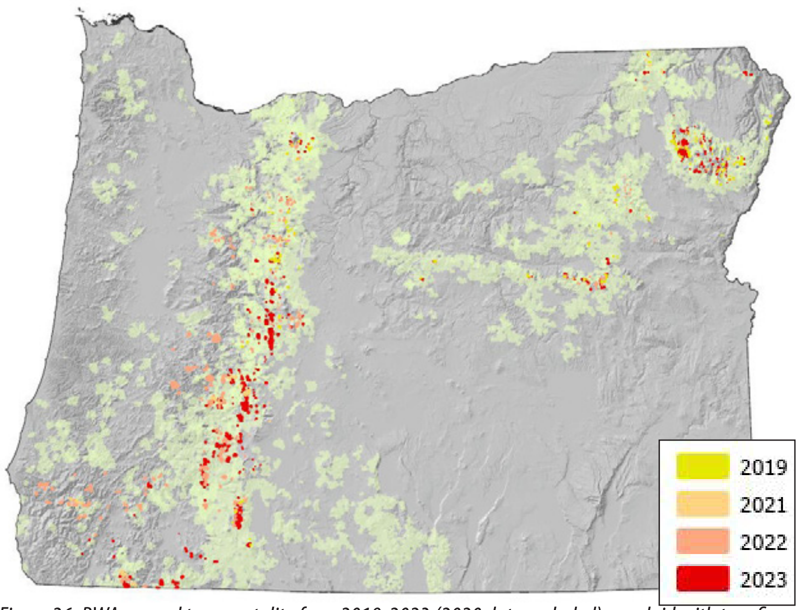


Figure 26. BWA-caused tree mortality from 2019-2023 (2020 data excluded), overlaid with true fir range (green). Perimeters enhanced for visibility.

EXOTIC PEST: **Spongy moth** (prev. European gypsy moth, *Lymantria dispar dispar*) is the European subspecies of this defoliating insect. It is established in eastern parts of the U.S. and routinely detected 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 Oregon 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. European 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 2023, the Oregon Department of Agriculture reported seven European spongy moths found across Benton, Marion, Washington, and Deschutes counties but no detected flighted spongy moths. Despite frequent introductions into the state, infestation of each subspecies found in Oregon has been successfully eradicated.

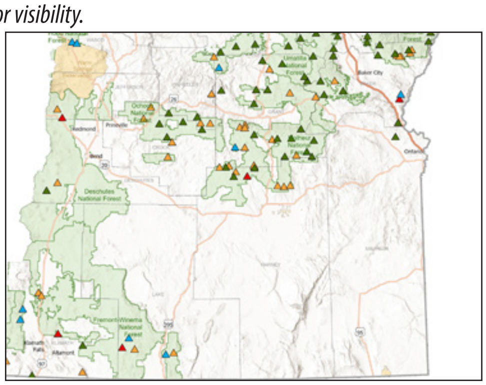


Figure 27. Douglas-fir tussock moth trap catches in 2023.

EXOTIC PEST: **Mediterranean oak borer** (MOB, *Xyleborus monographus*) is a tiny woodboring beetle (Fig. 28) that is native from Europe through northern Africa to the Middle East, and a recent arrival to North America. It was first detected killing valley oak (*Quercus lobata*) in Napa and Sonoma counties of central California in 2017, and is suspected to have arrived around the 2010s. In Oregon, a single beetle was captured in Multnomah County in 2018 and since then it has been captured in additional traps in Multnomah, Clackamas, Marion, and Washington counties. Starting in 2022, a single infested white oak, which has been destroyed, was found in Multnomah County and has since been destroyed. Approximately 30 infested trees have been found in Clackamas County, several of which have been destroyed.

Figure 28. MOB adult (Univ. of California - Riverside).

MOB is a type of ambrosia beetle, which does not feed on wood. Instead, it creates galleries in sapwood inoculated with fungi to feed its young. The fungi are visible as a black stain and cause wilt disease which kills the tree. The most visible signs and symptoms of this pest (Fig. 29) include dieback of a whole branch or portion of the crown, pale boring dust along bark crevices or around the base of the trunk, and black-stained galleries that cut across the sapwood and may be observed in the trunk or branches.

Figure 29. MOB infestations result in dieback of whole portions of crown (left), pale boring dust (center), black-stained galleries in sapwood (right) (Christine Buhl, ODF).

Currently the most effective treatment is to chip or burn the tree on site. We strongly urge against moving firewood to prevent the spread of this and other pests. There is much to be learned about this new pest and a joint Oregon and California multi-agency task force is working to:

1. Expand trapping efforts to determine MOB distribution, potential pathways, and timing of emergence
2. Evaluate other potential management strategies (e.g., burial of infested material, repellent pheromones, presence of parasitoids)
3. Expand detection trainings

MOB resources:

ODF factsheet: https://tinyurl.com/MOB-oregon
Other oak pests: https://www.oregon.gov/odf/Documents/forestbenefits/oak-pests.pdf
Invasive hotline reporting: https://oregoninvasiveshotline.org/reports/create
MOB infestation map: https://oda.fyi/MOBMap

EXOTIC PEST: **Emerald ash borer** (EAB, *Agrilus planipennis*) is an invasive woodboring beetle (Fig. 30) that attacks ash trees and was first detected in Oregon in 2022. In 2023 several survey and monitoring projects took place across the state, involving numerous state, federal and local agencies and landowners. The project coordination occurred through ODA and the Emerald Ash Borer Task Force; the members of which meet monthly to discuss recent findings and plan future surveys and management. By the end of 2023, results of several survey and monitoring projects demonstrated that the current extent of EAB in Oregon is a 10.4 square mile area centered in Forest Grove. Over 5,200 individual ash trees were individually inspected by ODA and partner agencies since July 2022. Accounting for all survey types described below as well as public reports of EAB, there were 190 trees (3.6%) found infested with EAB by the end of 2023 (Fig. 31).

Figure 30. Adult EAB (left, Steven Valley, ODA) and EAB larval gallery under ash bark (right, Troy Kimoto, Canadian Food Inspection Agency).

Statewide EAB trap survey: The 2023 field season was the first year of ODA's *Slowing ash mortality* program (SLAM) in which several riparian areas with ash were identified within a 2-mile radius of the 2022 ground zero. After receiving landowner permission, 109 ash trees were girdled by ODA in the spring before the EAB flight period. These trees acted as nearby "sinks" for capturing the expanding population of EAB. Adjacent to these girdled trees, nearly 200 additional Oregon ash trees were injected with a systemic insecticide to kill any "spillover" of attacks by EAB. The SLAM approach not only concentrates and slows the growth rate of the local EAB population, it provides a means to sample where the EAB population is moving on the landscape. The 109 girdled ash trees were felled in the fall and 1meter branch and trunk sections were carefully dissected to quantify the density of developing EAB larvae. Of the 109 girdled trees, 17 showed signs of EAB attack and colonization.

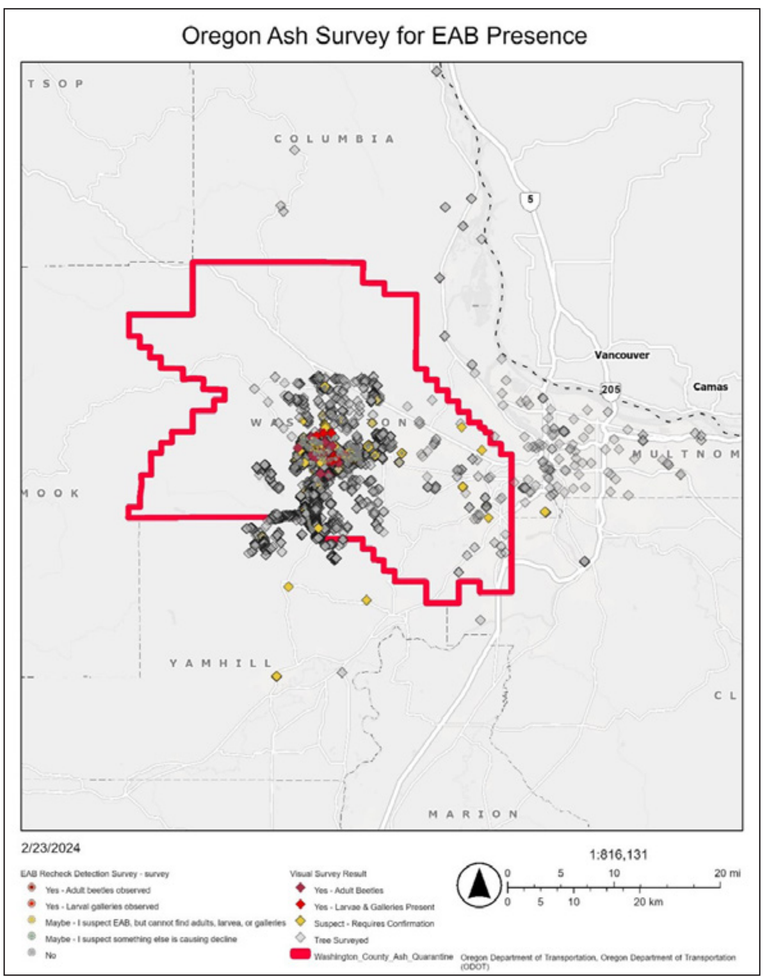


Figure 31. Ash trees surveyed for EAB by ODA and partners. By the end of 2023, EAB was known to occupy a 10.4 sq. mi. area around Forest Grove, Oregon. Since 2022, more than 5,000 individual trees have been inspected.

Across the 17 infested trees, there were 221 individual EAB observed, mostly in the larvae and prepupal stage. Material from all infested trees was destroyed. Patterns of infestation on the landscape show that the current EAB population is most dense along Council Creek north of Forest Grove. Other concerning areas of detection include along the Tualatin River and Gales Creek, south and west of Forest Grove, where large stands of Oregon ash currently occur.

In 2023, the USDA Animal and Plant Health Inspection Service (APHIS) provided purple prism traps, green funnel traps, and plant volatile lures to local governments and other cooperators who wanted an additional method of surveying for EAB in their jurisdictions. ODF Forest Health delivered trap supplies and provided methods and technical assistance to those local governments, organized incoming data and provided a real-time web map of trap locations. Trapping season started in May and concluded at the end of September. No EAB were observed in any of the 153 traps placed in 2023. Agencies that participated in placing EAB traps in 2023 included: the Cities of Beaverton, Corvallis, Hillsboro, Portland, Salem and Tigard; Metro; Columbia, Tualatin and Multnomah Soil and Water Conservation Districts; ODF, OSU, and the USFS.

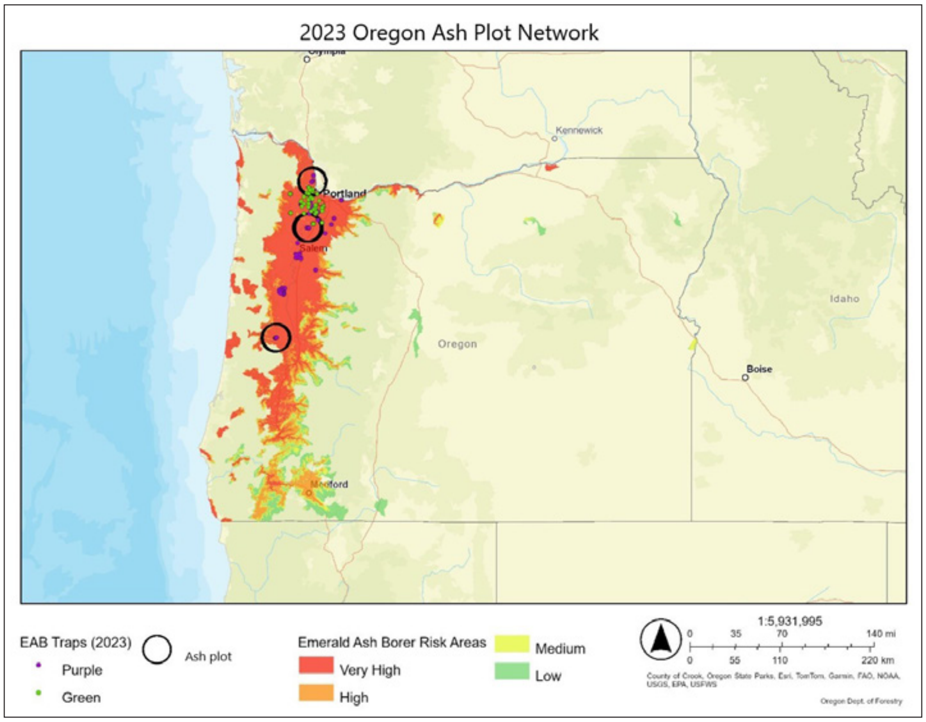


Figure 32. Locations of 2023 EAB traps and Ash Plot Network for survey and monitoring. No EAB were detected in 2023 in either the trap survey or the plot network.

Oregon Ash Plot Network: Because EAB is expected to expand its range in the Pacific Northwest over time, it is important to measure baseline conditions of Oregon ash forests before they are altered by significant tree mortality caused by the invasive insect. To capture current ash forest conditions before, during and after EAB invasions, the Oregon Ash Plot Network was successfully established at three sites in 2023 (Fig. 32). These plots were developed in partnership with Oregon Parks and Recreation Department (Champoeg State Park), Oregon Department of Fish and Wildlife (Sauvie Island), and a privately owned holding (Oregon Country Fair). Three fixed-radius plots, each with a diameter of 37 feet (plot area = 1/10th acre) were set up at each location for a total of 9 plots. For each plot, tree species, diameter at breast height, tree height and crown classifications were recorded. Across all sites and plots, 169 ash trees (82% of total) were measured and recorded. Seven other hardwood tree species (18% of total) were observed in the plots. No EAB symptoms or signs were observed for any of the ash trees. Drone imagery was captured for most of the plots. Methods and results were shared with Oregon State University Extension and Bureau of Land Management who also initiated similar ash monitoring plots in 2023.

Public Reporting of EAB: multiagency staff assisted in responding and evaluating the incoming reports to the state's official online hotline for invasive species. There were 77 reports for suspected EAB across the state in 2023. Forty-three percent were unidentifiable due to a lack of information. Of the remaining 44 reports, six reports, or 8%, were positive for EAB, all within the Forest Grove EAB-infested area. The number of positive EAB reported to the hotline in 2023 was similar to that of 2022. About a quarter of the reports were determined to be two common native woodborers, western cedar borer and golden buprestid.

EAB resources:
Multiagency EAB information: https://www.oregoninvasivespeciescouncil.org/eab
EAB infestation map and dashboard: https://geo.maps.arcgis.com/apps/dashboards/e6ff6b60f63b4c489cdee61315a85535
Invasive hotline reporting: https://oregoninvasiveshotline.org/reports/create

FOREST DISEASES

Figure 33. Mortality of a tanoak stand attributed to SOD in southwestern Oregon.

Sudden Oak Death (SOD), caused by the non-native invasive pathogen *Phytophthora ramorum*, causes mortality in tanoak (*Notholithocarpus densiflorus*) (Fig. 33) and infects more than 170 plant species, including several Oregon native plants. 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 nearby host plants (Fig. 34). Treatments include cutting and burning infected and potentially exposed host material. To monitor sudden oak death disease spread and detect new infestations, the Oregon SOD program relies on multiple survey methods conducted throughout the year, including aerial detection surveys augmented by high-resolution digital imagery and ground verification, ground-based transects, and stream monitoring.

Figure 34. SOD crew sampling a canker (dead lesion) underneath the bark of a tanoak (Gabi Ritokova, ODF).

In July 2023, the US Forest Service/Oregon Department of Forestry cooperative aerial detection survey team conducted a fixed-wing survey, followed by a helicopter survey, across forested lands in Curry County to monitor disease spread and detect new infestations. The aerial surveys covered 787,500 acres of forested land. To complement these surveys, the Oregon SOD program foresters analyzed 2023 high-resolution imagery outside of the Generally Infested Area (GIA) to identify declining or dead tanoak trees. The imagery project area now covers approximately 539,000 acres (842 square miles), covering the region between the California border and Coos County.

Ground surveys covered 860 acres and 518 trees were sampled, of which 117 were positive for *Phytophthora ramorum*. SOD foresters conducted ground transect surveys covering 210 acres for the harvest of disease-free tanoak on private lands. Tanoak harvest is only allowed following the issuance of a special permit by the Oregon Department of Agriculture under OAR 603-052-1230, Oregon's *P. ramorum* quarantine. Other SOD survey and detection efforts within and adjacent to the SOD quarantine area in 2023 included monitoring 63 stream bait sites (Fig. 35). From the initial installation of stream baits in May 2023, 26 streams tested positive for *P. ramorum* at least once during the 7-month baiting period.

Efforts to quarantine and slow the spread of *P. ramorum* continue along the southwestern Oregon coast. Twenty nine new infestations have been detected beyond the GIA in 2023. Assuming a 600-foot treatment buffer inclusion, the treatment area for the 2023 infections totals approximately 526 acres on State and private lands and 141 acres on federal lands. Since the 2021 detection of the third clonal lineage of *P. ramorum* (NA2) outside the Quarantine zone, new infestations have been detected within Humbug Mountain State Park and, more recently, south of Port Orford in the Hubbard Creek drainage (Fig. 36).

In 2023, 59 samples from the Humbug Mountain area tested positive for *P. ramorum*, and treatments have followed on 165 acres of private and State lands. In the treatment area within the Port Orford infestation, 347 acres have been treated, 56 acres are currently under active treatment, and another 477 acres remain untreated (based on 600-ft buffers around trees positively identified as being SOD infected). From 2001 through 2023, ODF's Slow the Spread SOD program has completed eradication treatments on more than 9,000 acres at an estimated cost of over $37 million. Federal lands comprised 28% of treated acres; the remaining area was private and State lands.

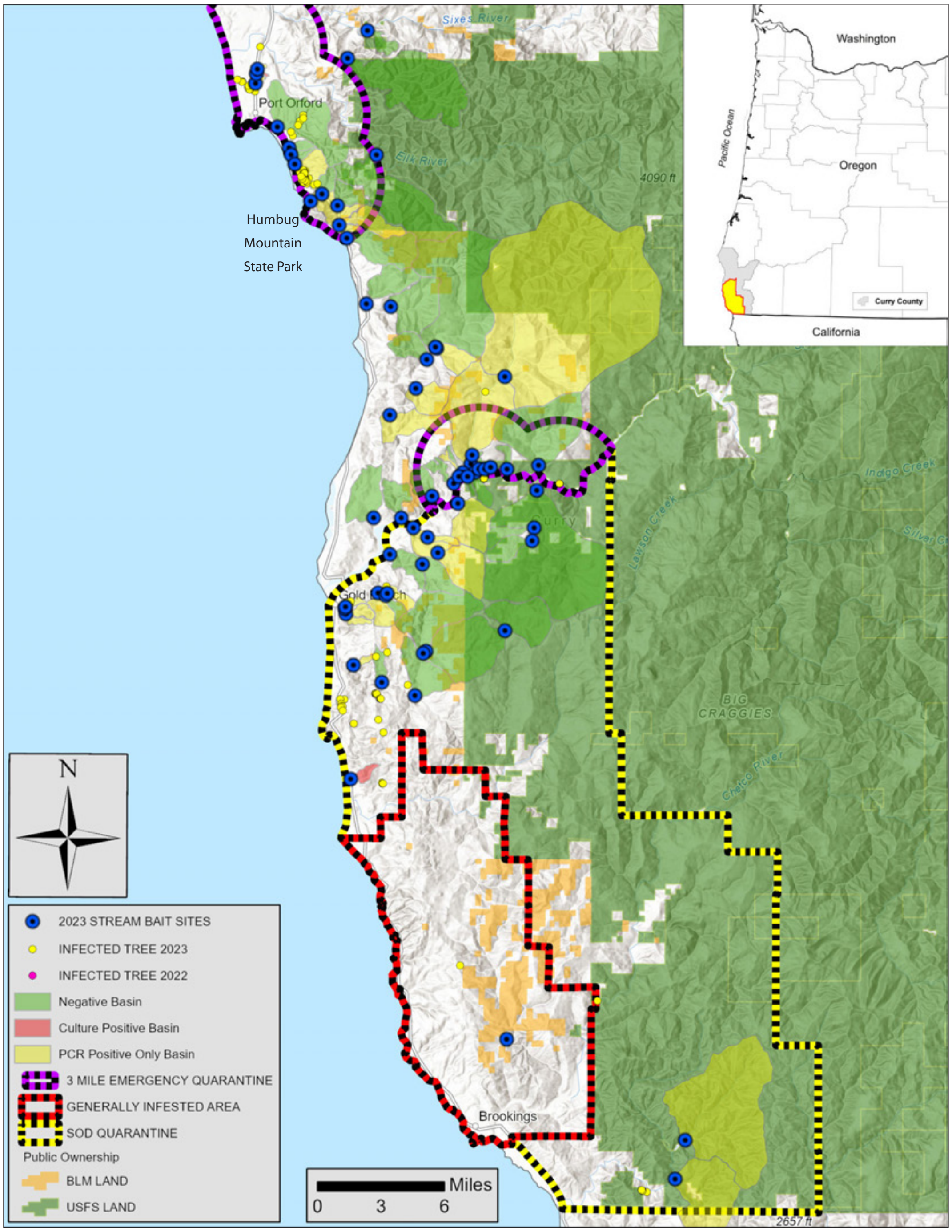


Figure 35. Stream baiting drainages. Green drainages indicate negative and the red drainage indicates positive Phytophthora ramorum presence. Yellow indicates that the drainage tested positive for P. ramorum with molecular testing.

SOD resources:
http://tinyurl.com/SOD-Program
http://tinyurl.com/SOD-Guide
http://tinyurl.com/odf-foresthealth

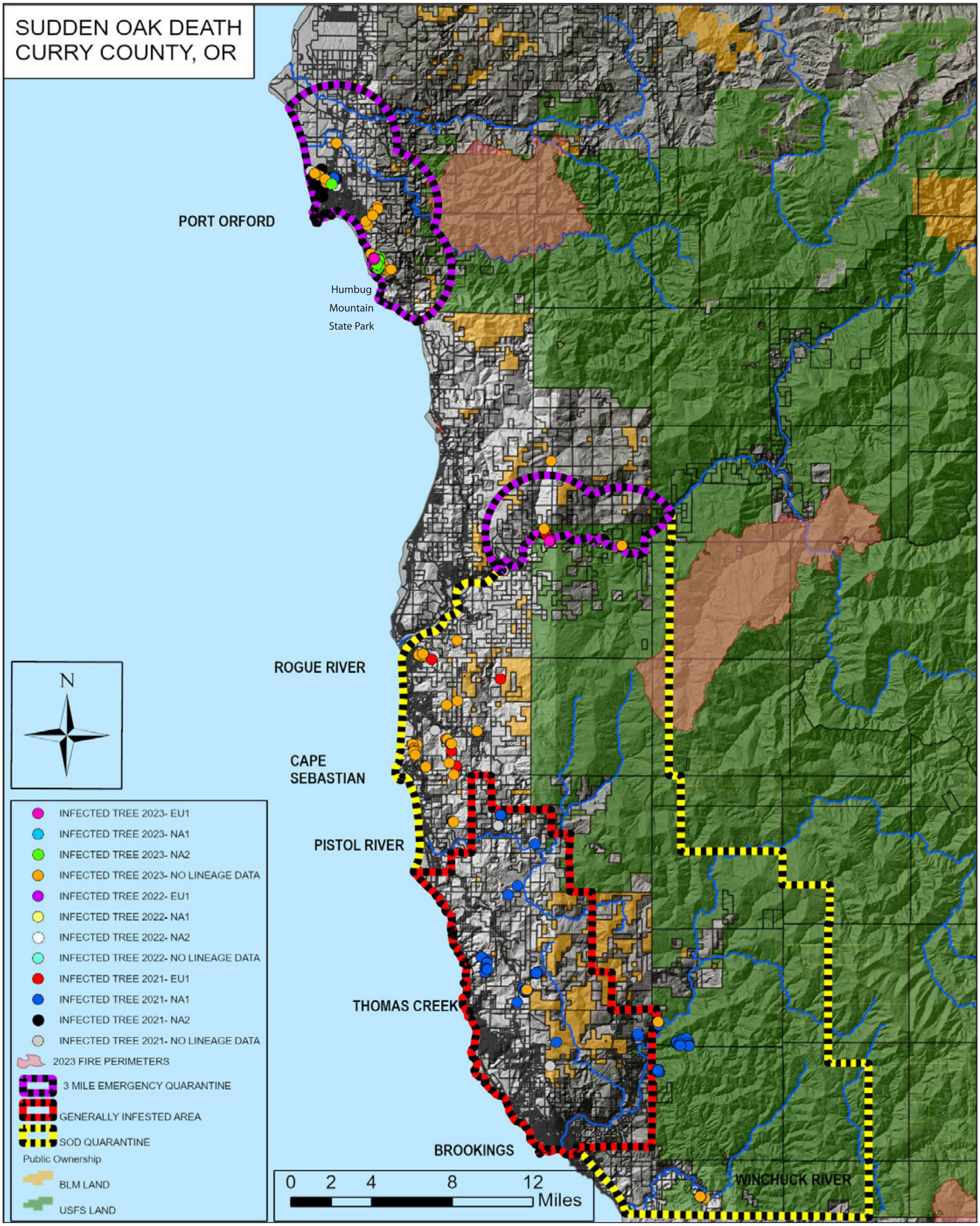


Figure 36. Location of infested sites with Phytophthora ramorum in southwestern Oregon discovered in 2021-2023.

Swiss needle cast (SNC), caused by the fungus *Nothophaeocryptopus gaeumannii*, is one of the most important foliar diseases affecting coastal Douglas-fir in the Pacific Northwest. Despite its name, "Swiss" needle cast is native to North America. This disease mostly causes damage along the coast of Oregon, stretching approximately 25 miles inland from the coastline. Beyond 25 miles inland, the disease can also cause problems on microsites, where the topography (southern aspects, low-elevation valleys) and climatic conditions are conducive for disease development. The Oregon coastal strip tends to have mild winter temperatures and high moisture levels in the spring and summer, supporting the successful growth and development of the pathogen. SNC symptoms include yellowing of infected foliage and decreased foliage retention, resulting in sparse crowns and reduced tree diameter and height growth (Fig. 37). The yellowing (chlorotic) signature is best observed by aerial detection surveys (ADS) in the spring immediately prior to budbreak. ADS for SNC covers approximately 3.5 million acres of the Oregon Coast Range and the Cascade foothills and is conducted every two years (even years). Since 1996, the symptomatic acres have been increasing, with an all-time high recorded in 2022 (Fig. 38). Since only moderate and severe symptoms are visible from the air, the ADS method is considered an underestimated representation of disease distribution.

Figure 37. Symptoms of SNC include chlorotic foliage and low foliage retention in Douglas-fir (left). The impact of SNC on growth can be seen in two 40-year-old stands planted at the same time, ~3 miles from the coastline (right). Douglas-fir is the stand on the right versus the western hemlock stand on the left. The western hemlock trees are larger and create more shade, whereas Douglas-fir are smaller and have thin crowns, allowing light penetration to increase understory vegetation growth (Gabi Ritokova, ODF).

In the fall of 2013, the Swiss Needle Cast Cooperative (SNCC) at Oregon State University began establishment of a research plot network (RPN) in 10-25 year old Douglas-fir plantations along the entire Oregon coast and part of southwest Washington to 35 miles inland (Fig. 39). The objectives of the RPN are to: 1) monitor SNC symptoms and tree growth in 10-25 year old Douglas-fir plantations throughout the Oregon Coast Range and southwest Washington, and 2) provide an improved estimate of growth losses associated with a given initial level of SNC. During the five-year period of the RPN's first remeasurement effort in 2018-2021, estimated cubic growth losses were as high as 35% with tree foliage retention of 1 year. In 2023, the second five-year remeasurement of the first third (30 plots) of the RPN was completed. The negative effect of SNC on cubic volume growth during the second 5-year period was compared to that on the same plots during the first five-year period. The negative effect of SNC due to diminished foliage retention was found to be ~23% greater during the second period for the lowest estimated initial foliage retention (1.2 years), implying growth losses that are similar to those found during an initial period of monitoring (1998-2008).

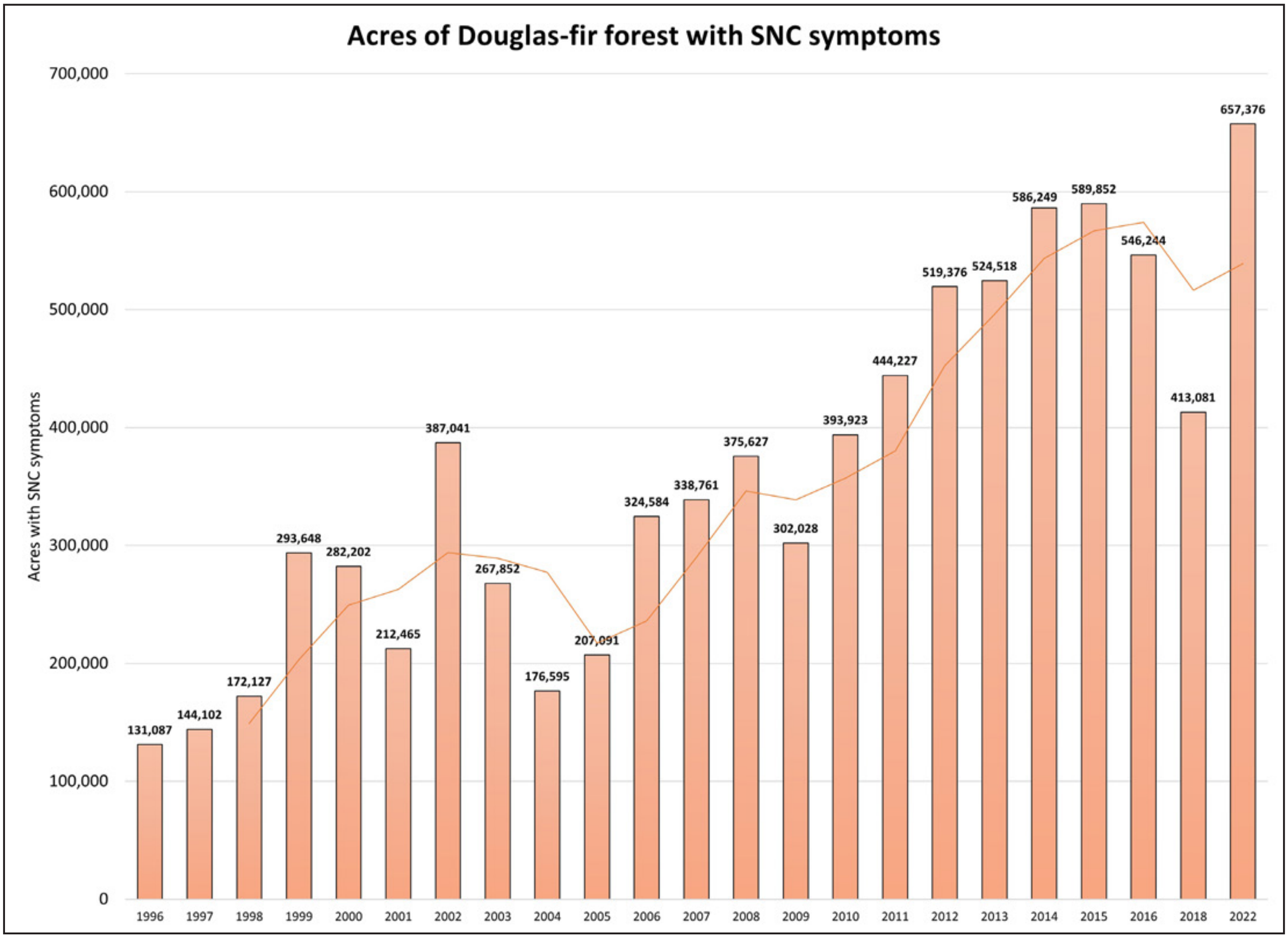


Figure 38. Acres of Douglas-fir forests with SNC symptoms as observed from aerial surveys conducted in late spring from 1996 to 2022. Surveys were not flown in 2017 or from 2019 to 2021. The red line reflects average acres across all survey years.

In addition to the research and monitoring plot network along the coast, disease conditions within the foothills of the Cascade Mountains were observed using a network of monitoring transects. Thirty one transects were installed in 10-19 year old Douglas-fir stands in the spring and summer of 2023, replacing a retired network of monitoring transects installed in 2017. Transects will be surveyed annually with the aim of evaluating SNC conditions using an index rating system for disease severity and foliage retention. The first assessment of the updated transect network suggests a strong relationship between foliage retention and elevation, with foliage retention greater than 2.8 years in transects located above 1,900 feet. Across surveyed stands, the SNC disease severity ranged from 1.2 to 2.1, light to moderate levels of infection, with mean disease severity at 1.73. Foliage retention ranged from 2.0 to 3.3 years of needles retained with a mean retention of 2.83 years of needles retained.

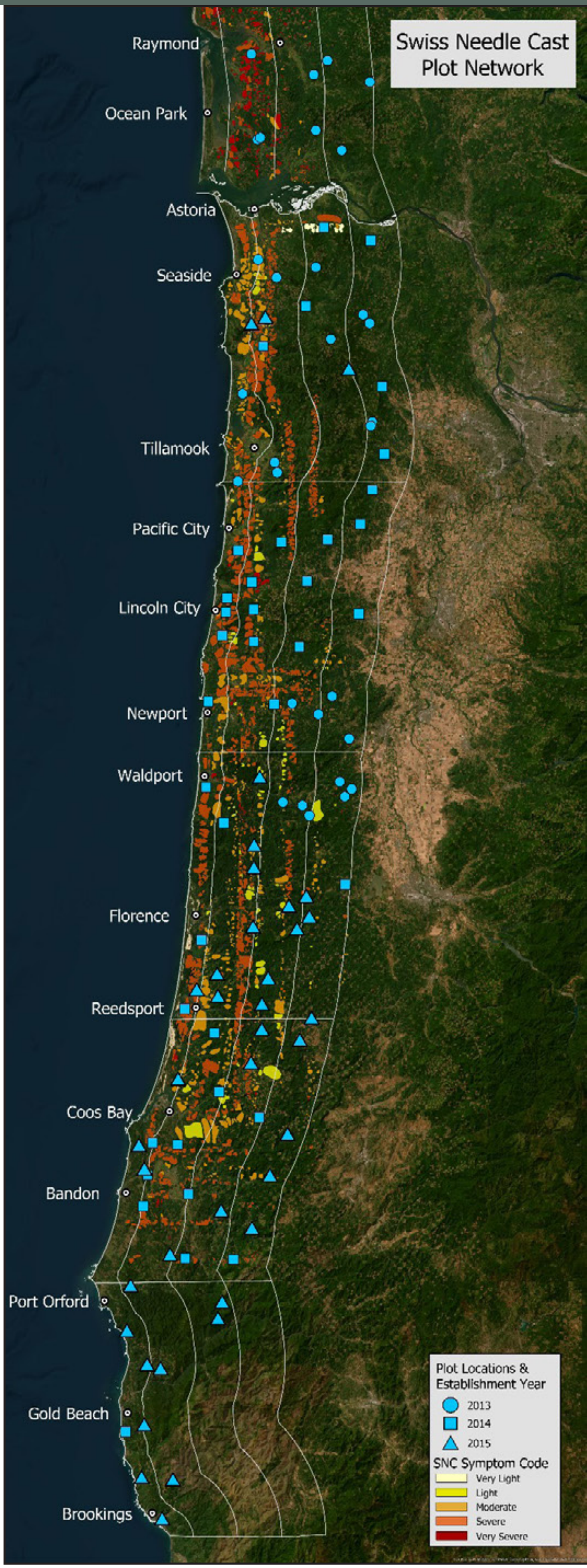


Figure 39. Map of the SNCC research plot network and the Cascade foothills transects.

In 2023, the SNCC piloted a spore-trapping study in collaboration with Dr. Miloň Dvořák of Mendel University in the Czech Republic. The goal of this project was to investigate the seasonal and spatial spore dispersal patterns of *N. gaeumannii* across the landscape. Three rotating arm spore traps (Fig. 40) were deployed in a heavily SNC-infected coastal Douglas-fir stand near Pacific City, Oregon. The traps were deployed for a 24-hour sampling period after which time the collected samples were transported to Oregon State University for processing. The results of the study are pending. The measurements following the calibration of the spore traps indicate that the design of these instruments is well-suited for capturing the targeted particle size of *N. gaeumannii* spores.

Figure 40. Rotating spore traps deployed in heavily infected SNC stands (Gabi Ritokova, ODF).

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

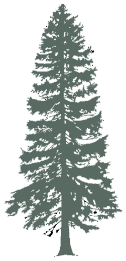
IMPORTANT INSECT AND DISEASE PESTS

	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	• Heterobasidion root disease • Cytospora canker • 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

IN NATIVE OREGON TREES

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**
• Heterobasidion 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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https://tinyurl.com/odf-foresthealth

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https://www.fs.usda.gov/main/r6/forest-grasslandhealth/insects-diseases

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