Forest Health Highlights in Washington / 2022

A summary of insect, disease, and other disturbance conditions affecting Washington's forests

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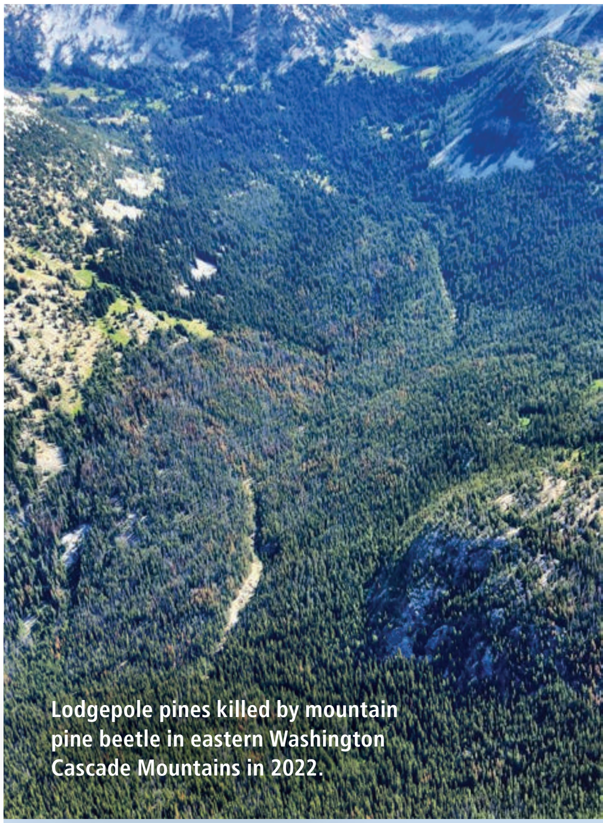
Washington State Department
of Natural Resources (DNR)
Forest Resilience Division
April 2023

WASHINGTON STATE DEPT OF
NATURAL RESOURCES
HILARY S. FRANZ
COMMISSIONER OF PUBLIC LANDS

Summary

This is the 76th year of interagency coordination between the USDA Forest Service (USFS) and Washington State Department of Natural Resources (DNR) on an annual insect and disease aerial detection survey (ADS). Since 1947, the two agencies have flown over millions of acres in Washington each year to observe recently killed and currently damaged forest trees.

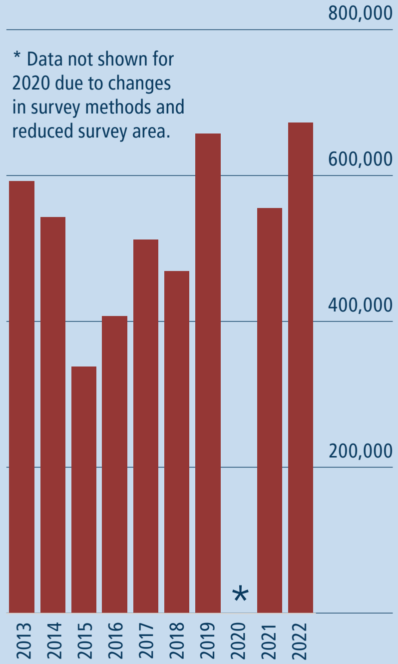
In 2022, surveyors covered approximately 22 million forested acres across Washington. The 2022 season marked the first time survey operations returned to normal since the COVID-19 pandemic, which influenced operation protocols in 2020 and 2021. Approximately 13% of forested acres typically surveyed in the state were not included in 2021 due to fire activity, aircraft availability, and observer availability. No survey flights were conducted in 2020 in order to lower risk of COVID-19 exposure and spread among flight crews and their contacts. In place of aerial surveys in 2020, the data used for statewide insect and disease surveys were acquired through a combination of ground sampling and remote sensing.


ISAAC DAVIS / DNR

Lodgepole pines killed by mountain pine beetle in eastern Washington Cascade Mountains in 2022.

- **In 2021, the statewide insect and disease survey recorded some level of tree mortality, tree defoliation, or foliar diseases on approximately 672,000 acres.** The area with damage from mortality agents was approximately 604,000 acres, including 346,000 acres attributed to bark beetles and 129,000 acres attributed to bear damage or root disease. Approximately 33,000 acres with damage were attributed to defoliators and approximately 35,000 acres were attributed to tree diseases or other damage causes. Previous annual totals for all damage agents were:

2021: 555,000 acres with damage out of approximately 19 million acres surveyed
2020: 322,000 acres with damage out of approximately 10.5 million acres surveyed
2019: 658,000 acres with damage out of approximately 22 million acres surveyed
2018: 469,000 acres with damage out of approximately 22 million acres surveyed
2017: 512,000 acres with damage out of approximately 22 million acres surveyed



TOTAL ACRES WITH INSECT AND DISEASE DAMAGE 2013-2022

- **All of Washington experienced some level of drought conditions by fall of 2022, despite above-normal spring precipitation.** Drought conditions and warm, dry spring weather tend to increase tree stress and insect success, increasing the number of acres with damage in both the current and subsequent year. Wet spring weather tends to increase acres affected by foliage diseases and bear damage in both the current and subsequent year. Precipitation in Washington was above normal in spring 2022, but below normal in both summer and fall. Monthly average temperatures were below normal in spring 2022, but above normal in summer and fall. According to the U.S. Drought Monitor, all of Washington experienced some level of drought condition by fall of 2022. By late October, all of western Washington ranged from severe to moderate drought condition, while all of eastern Washington was in abnormally dry to moderate drought condition.

- **The area with mortality caused by pine bark beetles in 2022 was approximately 123,700 acres. Mountain pine beetle** damage increased from 53,100 acres in 2021 to approximately 76,800 acres in 2022. The majority of annual pine bark beetle mortality is in lodgepole pine killed by mountain pine beetle, which totaled 66,800 acres in 2022. Surveyors mapped the highest concentrations of mountain pine beetle mortality in lodgepole at high elevation areas of Yakima, Kittitas, Chelan, Okanogan, Ferry, and Pend Oreille counties.

- **Mortality of ponderosa pine due to western pine beetle has increased steadily since 2012 and reached a peak of approximately 44,300 acres in 2022,** the highest level since 2006. Recent drought conditions are likely an important driver of these increases. The highest concentrations of western pine beetle-caused mortality were throughout forested areas of Klickitat County and the Yakama Indian Reservation, central Kittitas County, eastern Okanogan County, the Confederated Tribes of the Colville Reservation, throughout Stevens and Spokane counties, and the Blue Mountains in southeast Washington. Mortality attributed to **Ips pine engravers** was mapped on 2,500 acres in 2022, above the 10-year average of 1,700 acres.

- **Mortality due to Douglas-fir beetle has been increasing in recent years, reaching a 10-year high of approximately 105,000 acres in 2022,** well above the 10-year average of 43,000 acres and the highest level recorded since 2001. **Fir engraver** caused mortality, primarily in grand fir, had been steadily increasing since 2015 and reached a 10-year high of 166,300 acres in 2019. Since then it has declined to approximately 65,700 acres in 2022.

- **Chronic infestations of the non-native balsam woolly adelgid affected approximately 30,000 acres in 2022,** accounting for the majority of defoliation damage in Washington. Damage was primarily in subalpine fir at high elevations in the Olympic, Cascade, and Selkirk mountain ranges. No **Douglas-fir tussock moth** defoliation has been recorded in eastern Washington since the 2018-2019 outbreaks in Kittitas, Chelan, and Okanogan counties collapsed. No new **western spruce budworm** defoliation was observed from the air in northeast Washington, where the most recent outbreak is declining.

- **Swiss needle cast aerial and ground surveys indicate no consequential change.** Aerial observers conducted a Swiss needle cast aerial survey in May 2022, covering 2 million acres along and near the coastline. Approximately 115,000 acres with symptoms were observed. To support the aerial survey, 96 ground locations across the same coastal range of the aerial survey were assessed in spring 2021 and 2022. Additionally, during the same time period, 32 ground plots were surveyed in Whatcom and Skagit counties in an area where monitoring had not occurred before.

- **The fungus *Cryptostroma corticale*, which causes sooty bark disease of maples in Europe, continues to be detected in Washington.** Initially, this fungus was detected mainly around the Seattle area, but now samples have been found as far north as Bellingham, south into Oregon, and as far east as Pullman. These samples have confirmed the presence of *C. corticale* mainly on maple trees (*Acer* spp.), including on bigleaf maple (*Acer macrophyllum*), our only native canopy maple. A 2022 ground survey of 50 western Washington properties indicates that *C. corticale* on bigleaf maple appears well distributed throughout western Washington.

- **No notable changes regarding *Phytophthora ramorum*, the causal agent of sudden oak death, were observed in 2022.** *P. ramorum* is often found in streams associated with commercial plant nursery trade activity, but there has yet to be any indication that the pathogen is leaving the waterways and impacting bordering vegetation. No stream-baiting sampling locations tested positive for *P. ramorum* in 2022.

- **Some foliar diseases were notable in 2022. Western larch defoliation** was mapped on approximately 27,500 acres, an increase from the 3,300 acres mapped in 2021. Of the acres affected, lower crown defoliation due to larch needle cast (*Rabdocline laricis*) was mapped on approximately 27,300 acres, driving the increase. An outbreak of **powdery mildew** was observed on bigleaf maple in spring 2022 throughout western Washington. Similar to many foliar diseases, these will likely have minimal long-term impacts to healthy trees.

MOUNTAIN PINE BEETLE DAMAGE INCREASED FROM 53,100 ACRES IN 2021 TO APPROXIMATELY 76,800 ACRES IN 2022.

GLENN KOHLER / DNR

Drought-related mortality in Douglas-fir saplings in King County in 2015.

Abiotic Disturbances Influencing Forest Health

Abiotic disturbances – disturbances caused by non-living factors – are a natural and integral part of forest ecosystems. They are responsible for major impacts, both positive and negative, on our forests. They influence forest structure, composition, and function, and can be important for maintaining biological diversity and facilitating regeneration. Abiotic disturbances such as wildfire, drought, landslides, flooding, and extreme weather events can cause tree mortality. Surviving trees may be damaged or weakened by these events. This can indirectly influence forest health conditions, by making them more susceptible to attack by insects and pathogens. Abiotic disturbances that cause mortality and damage over large areas, such wildfire, windstorms, and drought, may provide enough breeding material to increase local bark beetle populations to the level of an outbreak. This can then cause mortality in healthy trees. Drought and other disturbances that compromise tree defenses can lead to increased levels of mortality from root disease and other forest pathogens. Unseasonal extremes in precipitation may lead to increased levels of foliar pathogens that cause diseases, such as needle casts and needle blights.

The following section is a summary of recent weather, drought, and wildfire events that may influence forest health conditions in Washington.

Weather

Severe weather events that injure or kill trees often make them more susceptible to attack by insects and pathogens. Examples include heat stress, winter damage (defoliation, cracks or breakage from cold, snow or ice), flooding, windthrow, landslides, and hail. Unusually wet spring or fall weather, such as what occurred in fall 2021 and spring 2022 **(Fig. 1)**, can increase the incidence of foliar diseases. Outbreaks of certain bark beetle species, such as Douglas-fir beetle or Ips pine engravers, follow weather or fire events that kill or injure numerous trees. Conifer trees killed by bark beetles typically do not appear red until the year after they died. Therefore, increases in mortality from bark beetles related to events such as drought or storms may not appear in aerial survey or remote sensing data until two years following the event. In years like 2022, when spring and early summer precipitation is above average and temperatures are below normal **(Fig. 2)**, issues with drought stress are reduced and trees are more likely to recover from injury, such as the heat scorch event that occurred in western Washington in June 2021.

Vigor and resilience to adverse weather can be increased by ensuring that trees have room to grow and are appropriate species for the site. For example, forests in eastern Washington are generally overstocked with too much fir, and without enough drought-tolerant pine and larch. These conditions favor defoliators such as western spruce budworm, perpetuate root disease, and encourage bark beetle activity. In western Washington, Swiss needle cast disease affects Douglas-fir trees growing on coastal sites that may be more suited to western hemlock and Sitka spruce.

Figure 1.

WASHINGTON STATE PRECIPITATION

Average monthly precipitation (blue line) and 30-year average (green line) for Washington.

SOURCE: WESTERN REGIONAL CLIMATE CENTER (HTTPS://WRCC.DRI.EDU/)

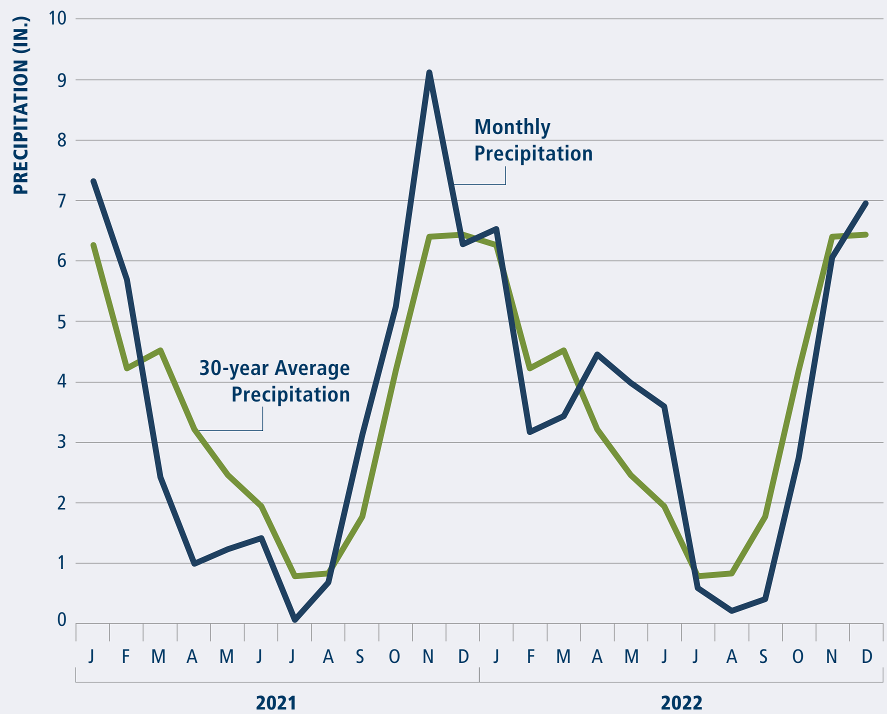
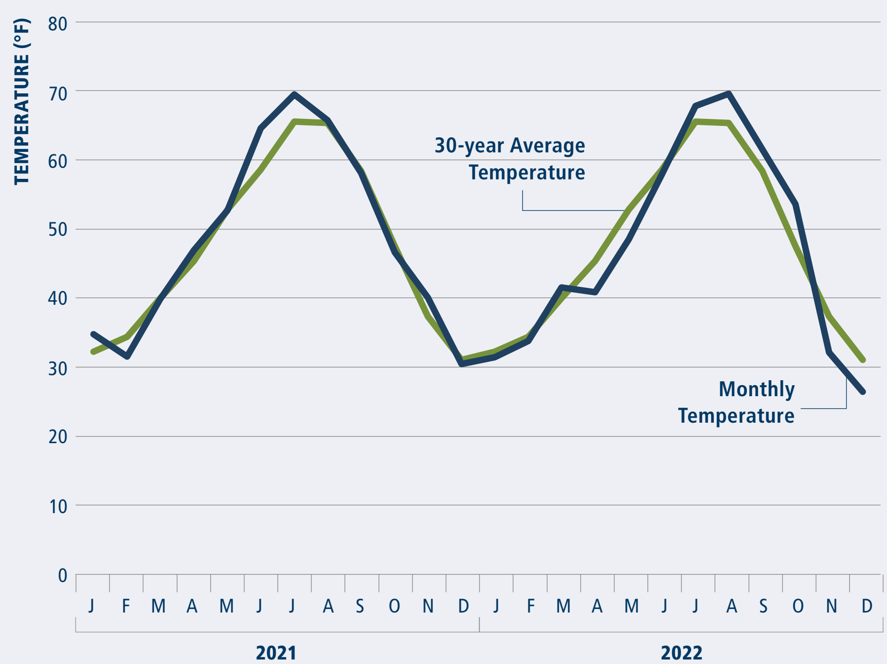


Figure 2.

WASHINGTON STATE MEAN TEMPERATURES

Average monthly temperatures (blue line) and 30-year average (green line) for Washington.

SOURCE: WESTERN REGIONAL CLIMATE CENTER (HTTPS://WRCC.DRI.EDU/).



Drought

Precipitation in Washington was well above normal in spring and early summer 2022. What followed was below normal rainfall during late summer and into fall, an inverse of 2021 precipitation measures **(Fig. 1)**. Monthly average temperatures in 2022 were above normal from July through October **(Fig. 2)**. A record-setting extreme heat event in June 2021 resulted in widespread tree needle desiccation damage in parts of western Washington. Lasting effects of this needle desiccation event in terms of mature tree mortality were not observed in 2022. Belc normal rainfall during the growing season may increas the potential for drought stress on trees; however, abc average precipitation throughout much of the growin season, as seen in 2022, may mitigate drought effects.

From January through May 2022, conditions in eastern Washington forests averaged from abnormally dry to moderate drought, with areas of severe drought in northeast Washington throughout May. Eastern Washington returned to abnormally dry-to-moderate conditions in September, and stayed dry for the remainder of 2022. Western Washington experienced drought conditions ranging from abnormally dry to severe drought from September through December 2022, with the most severe drought occurring on the Olympic Peninsula and westside Cascade foothills in late October **(Fig. 3)**. All of Washington experienced some level of drought condition in fall 2022. The areas of eastern Washington that experienced extreme drought in 2022 are largely non-forested regions of the Columbia River Basin **(Fig. 4)**. These conditions will likely increase tree susceptibility to insect and disease attacks, making them less likely to recover from injuries.

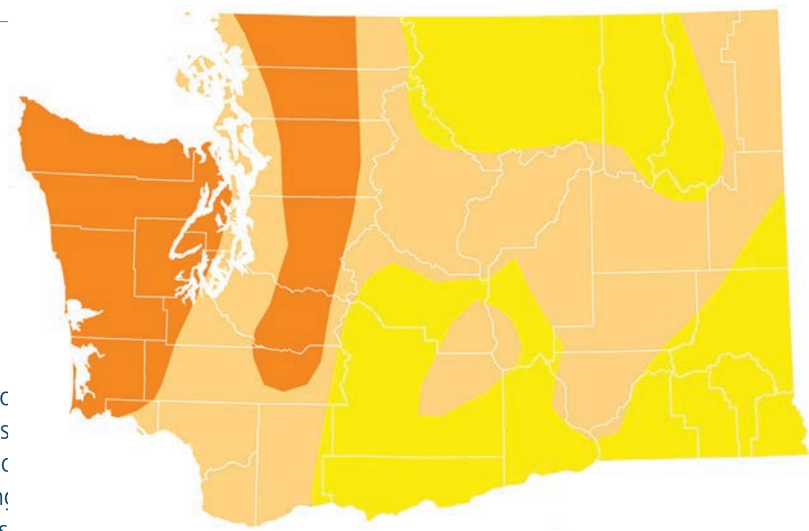


Figure 3.

DROUGHT CONDITIONS IN WASHINGTON AS OF OCT. 25, 2022

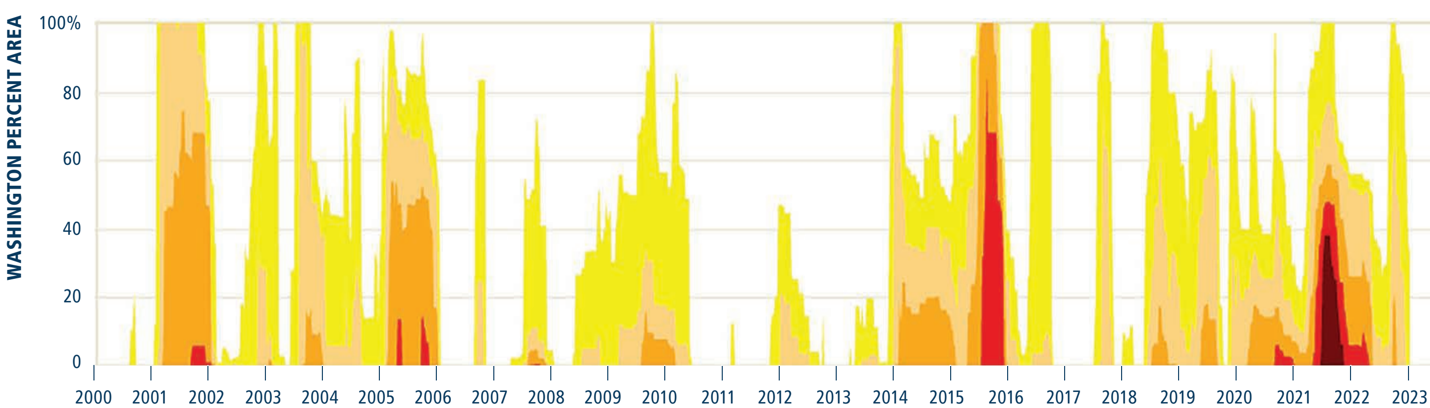
SOURCE: US DROUGHT MONITOR (HTTPS://DROUGHTMONITOR.UNL.EDU/)

No Intensity
Abnormally Dry
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought

Figure 4.

PROPORTION OF WASHINGTON STATE AREA AFFECTED BY DROUGHT FROM 2000 – 2022

SOURCE: US DROUGHT MONITOR (HTTPS://DROUGHTMONITOR.UNL.EDU/)



Wildfire

According to data compiled by the Northwest Coordination Center (NWCC) and DNR, wildfires burned 173,662 acres across Washington during the 2022 season, down from the 674,249 acres burned in 2021. According to a GIS analysis of statewide fire polygons intersected with the National Land Cover Database, estimates for large fire fuel types burned in 2022 were: 56% forest, 26% shrub-steppe, 13% grassland, and 5% other (i.e. agricultural lands, urban areas, wetlands).

There were 909 fires on DNR protected lands in 2022, down from 1,271 fires in 2021, and below the average of 953 fire occurrences per year over the period 2011 to 2020. Data shows 12% of these fires were natural (lightning caused), 64% were caused by humans, and the remaining 24% were of undetermined origins **(Fig. 5)**. Of the 1,633 total fire responses statewide in 2022 (including both DNR and other agency protected lands), 61 were considered "large fires" per NWCC definition for size (greater than 100 acres of forestland or 300 acres of brush/grass) **(Fig. 6)**, and 14 of those large fires included DNR involvement.

According to DNR fire occurrence data, the bulk of DNR's wildfire activity occurred later in the year, during the months of July, August, September, and October, although fires occurred in every month of the fire year, except January and December. Debris burning is the leading source of human-caused fire ignitions on DNR-protected lands.

Rain during the spring of 2022 translated to an abundant load grass fuels in the rangelands of eastern Washington. As conditions shifted to hot and dry patterns in July, these fine fuels dried out and posed a volatile fire threat. The first large DNR Fire of the year was the Stayman Flats Fire, which started July 18, just outside of Chelan, and burned 1,101 acres. The Vantage Highway and Cow Canyon fires occurred in the first week of August, just outside of Ellensburg, and burned a combined 36,470 acres. The Williams Lake Fire was discovered just south of Cheney the same day Cow Canyon started. It grew to nearly 2,000 acres. August was the busiest month, with over 300 incidents reported; however, the fuel and weather conditions late in the season also supported several escaped slash pile burns in the month of November.

A TALE OF TWO SEASONS

Washington's 2022 fire season began with the wettest April to June period on record, but ended with the driest July to October on record. The two extremes yielded a late start and a late peak to fire season. Record moisture through June led to an extended green up period. The lack of moisture through September precluded any season ending rainfall events on the numerous large fires in the Cascades **(Fig. 7)**. Overall, critical fire weather events were mainly driven by hot and unstable conditions in the Cascades associated with a persistent high pressure ridge over the state. Winds aloft (between 5,000 and 10,000 feet above sea level) were weaker than normal last summer, and led to only a handful of critical wind events. Two moderate east wind events (one in September and one in October) were the most critical periods of fire weather for the state, resulting in significant smoke impacts, rapid spread of existing fires, and the ignition of the Bolt Creek fire, which burned 14,715 acres.

ERIC KIEHN

THERE WERE 909 FIRES ON DNR PROTECTED LANDS IN 2022, DOWN FROM 1,271 FIRES IN 2021, AND BELOW THE AVERAGE OF 953 FIRE OCCURRENCES PER YEAR OVER THE PERIOD 2011 TO 2020.

Figure 6.

2022 WASHINGTON STATE WILDFIRES

Location of wildfires that occurred in Washington in 2022.

DATA SOURCES: NATIONAL INCIDENT FEATURE SERVICE 2021 (NIFC), WADNR FIRE STATISTICS 2022 (FIReS)

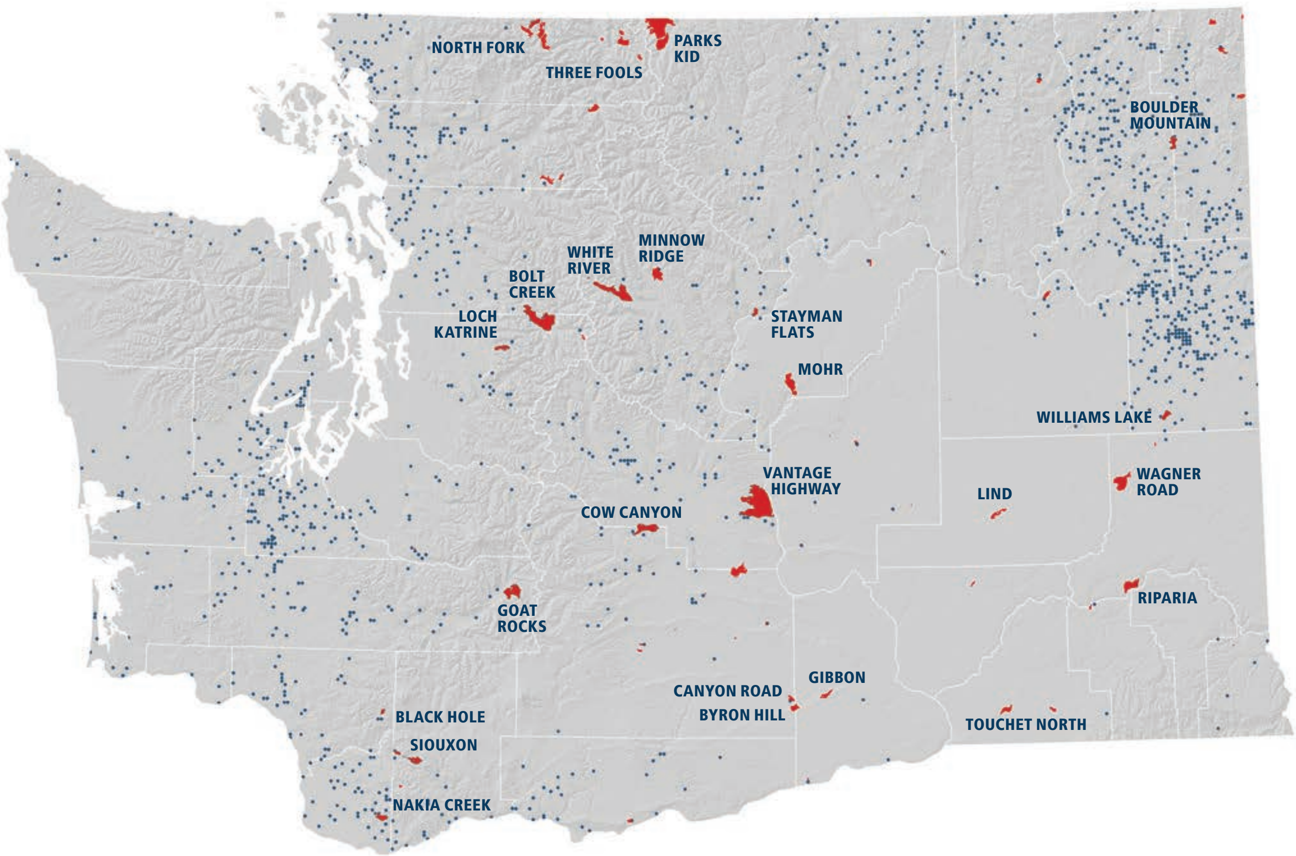
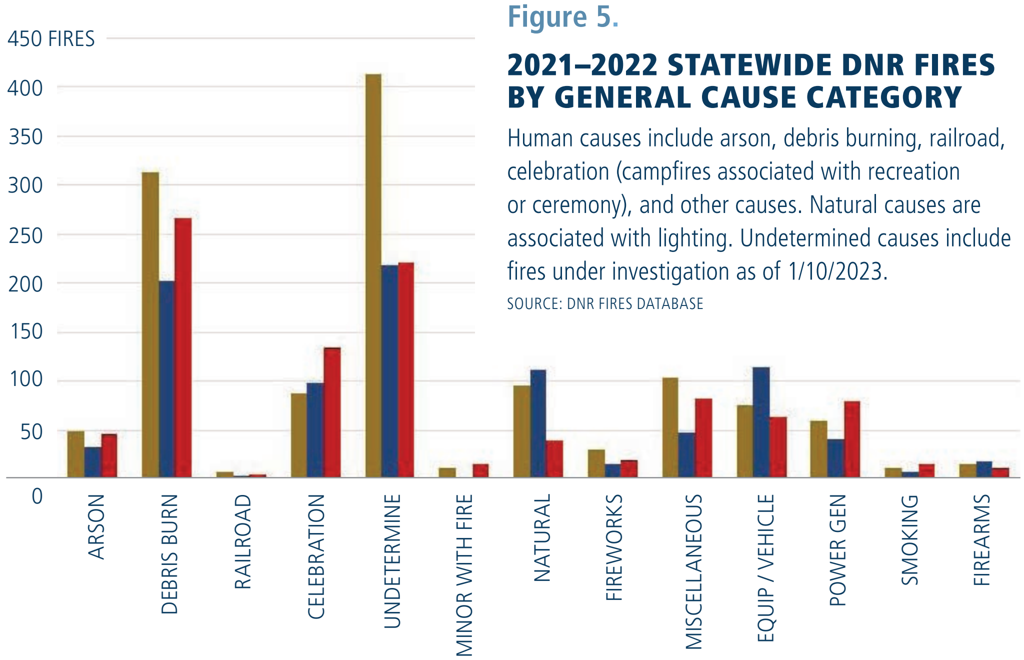


Figure 5.

2021–2022 STATEWIDE DNR FIRES BY GENERAL CAUSE CATEGORY

Human causes include arson, debris burning, railroad, celebration (campfires associated with recreation or ceremony), and other causes. Natural causes are associated with lighting. Undetermined causes include fires under investigation as of 1/10/2023.

SOURCE: DNR FIRES DATABASE



ISAAC DAVIS / DNR

The Diamond Watch Fire in Pend Oreille County in 2022.

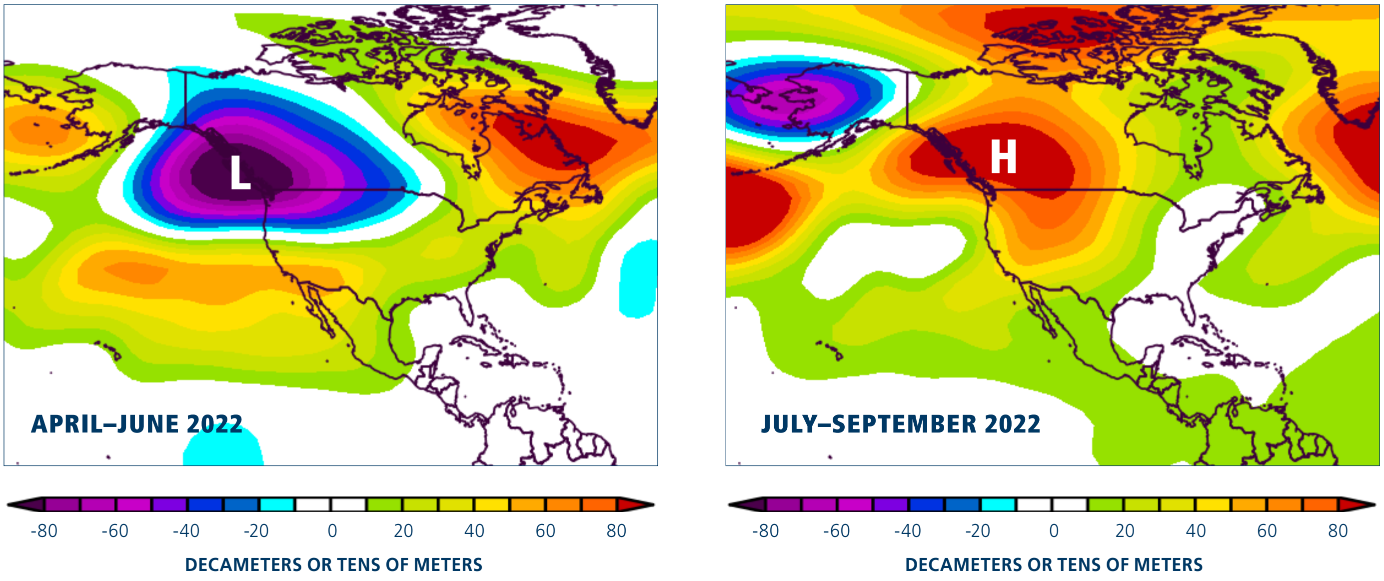


Figure 7.

UPPER AIR HEIGHT ANOMALIES

April to June (left) and July to September (right) exhibited directly opposite patterns. Persistent low pressure in the spring resulted in numerous late spring rainstorms that contributed to high fuel loading and extended the green-up period. Persistent high pressure through the summer and fall kept temperatures well above average and deflected any rain producing storms northward into Alaska.

SOURCE: NOAA

WASHINGTON'S FOREST ACTION PLAN UPDATE

Washington's Forest Action Plan was revised and adopted on October 26, 2020. The Forest Action Plan is a comprehensive review of forests across all lands — public and private, rural and urban — and offers proactive solutions to conserve, protect, and enhance the trees and forests that people and wildlife depend on. At a time when we were evolving our response to the COVID-19 pandemic, partners contributed and collaborated toward the development of an ambitious statewide plan. The plan identifies 23 goals and 159 priority actions across 8 themes to restore forest resilience and advance ecological, community, and socio-economic objectives. The plan also makes firm commitments to monitoring collective progress made by individual organizations and through partnerships, as well as to sharing successes and lessons learned along the way.

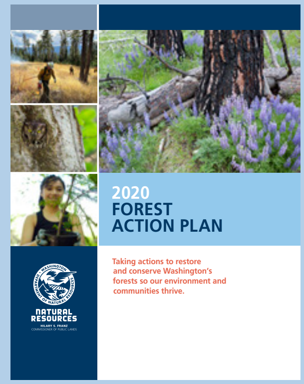
To date we have validated an assumption built into the plan's development: collaboration is a particular key to success. No one partner can do this work in a silo, and the cooperative efforts of our tribal nations, non-profit organizations, state, county, and federal agencies are vital. In 2022, partners have made tremendous progress implementing our Forest Action Plan. Highlights from the year are summarized in our annual report, available at **https://www.dnr.wa.gov/ForestActionPlan**. Throughout this report, we've connected report sections, success stories, sidebars, and graphics to specific Forest Action Plan goals or priority actions that are being moved forward.

In December 2022, DNR also reported on progress towards implementation of the 20-Year Forest Health Strategic Plan: Eastern Washington. The biennial report includes assessment of forest conditions to quantify forest restoration and management needs across 37 priority landscapes covering 4,165,780 acres in eastern Washington. Also featured are landscape evaluation summaries for eight priority planning areas, and a commitment to analyze 10 more priority planning areas next biennium (representing an additional 1,108,883 acres), and treatment tracking that reveals DNR and our partners have reported 493,460 acres of forest health treatments across eastern Washington since the plan's adoption in 2017 - impacting 309,556 footprint acres.

Cutting-edge forest health monitoring, in complement to the surveys in this report, is helping to track progress toward our goals while monitoring the effectiveness of forest health treatments in the face of wildfire, drought, and insects and disease. Read the full report: **https://www.dnr.wa.gov/sites/default/files/publications/rp_forest_health_treatment_framework_assessment_legislative_report_final.pdf**

The pioneering work of Washington, as guided by our State Forest Action Plan, is getting recognition across the west coast, and from decision makers at the national level. Washington hosted the 2022 National Association of State Foresters meeting in the Columbia River Gorge, as well as the Wildland Fire Leadership Council in Spokane. Leaders from across the country were able to hear from Washington's natural resource practitioners and see incredible all-lands, all-hands work firsthand.

Read the 2021-2022 Forest Action Plan annual report at https://www.dnr.wa.gov/ForestActionPlan



NO ONE PARTNER CAN DO THIS WORK IN A SILO, AND THE COOPERATIVE EFFORTS OF OUR TRIBAL NATIONS, NON-PROFIT ORGANIZATIONS, STATE, COUNTY, AND FEDERAL AGENCIES ARE VITAL.

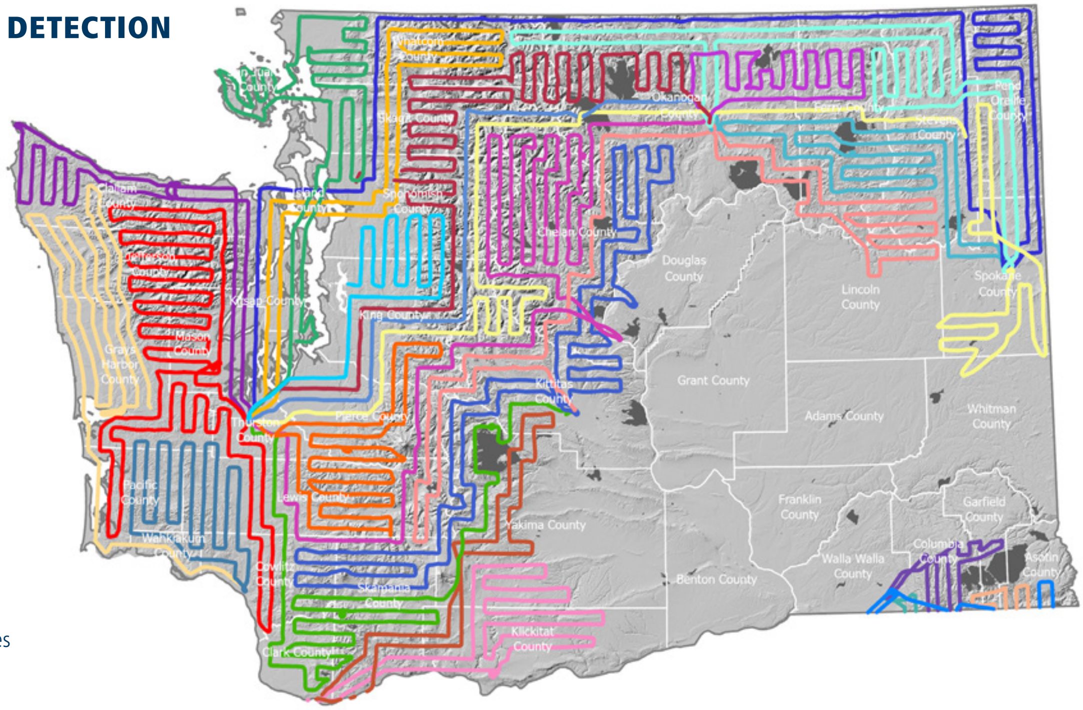
Figure 8.

WASHINGTON AERIAL DETECTION SURVEY FLIGHT LINES FOR 2022

SOURCE: DNR, USFS

FLIGHT DATES

- 6/27/22
- 6/30/22
- 7/01/22
- 7/19/22
- 7/21/22
- 7/29/22
- 8/01/22
- 8/02/22
- 8/03/22
- 8/04/22
- 8/05/22
- 8/11/22
- 8/15/22
- 8/16/22
- 8/17/22
- 8/18/22
- 8/22/22
- 8/23/22
- 8/24/22
- 9/08/22
- 9/15/22
- 9/16/22
- 9/19/22
- 9/20/22
- 9/21/22
- 2021-2022 Fires



Aerial observer using digital mobile sketchmapper.

Aircraft operated by the Washington Department of Fish and Wildlife that was used for portions of 2022 aerial detection surveys in Washington. Its high wing design allows observers a clear view of forests below.

GLENN KOHLER / DNR ; INSET: RACHEL BROOKS / DNR

Aerial Detection Survey

The annual insect and disease aerial detection survey (ADS) to detect recently killed and currently damaged forest trees in Washington is conducted by the USDA Forest Service (USFS) in cooperation with DNR, and has been ongoing since 1947. The 2022 season marked the first time survey operations returned to normal since the COVID-19 pandemic began. A fully staffed survey crew, along with one of the mildest fire seasons in a decade, allowed the collaborative program to take advantage of favorable weather conditions and stay ahead of larger, late-season fires. Excluding forests burned in 2021 and areas near restricted airspace, the entirety of Washington's 22 million acres of forestland were surveyed successfully, a significant improvement over the 87% surveyed in 2021.

The ADS in 2021 faced a number of complications, including widespread fire activity, aircraft availability, and position vacancies. Aerial surveys in the Pacific Northwest are often challenging without those impediments. Adverse weather conditions are frequent and can disrupt productivity of the survey season by introducing suboptimal visual conditions, or by putting safety at risk. This was nearly the case for the Swiss needle cast (SNC) aerial survey flown in May 2022. The damage signature of SNC is nuanced and detectable only in springtime prior to bud break. The uncharacteristically long, wet spring weather in western Washington kept survey aircraft grounded throughout April and most of May. Fortunately, surveyors were able to complete two full days of flights in May, finishing about a week before bud break. Completing the SNC survey stands as another notable success of the 2022 ADS season. See page 48 for more information on Swiss needle cast.

Summer fires in northeast Washington occasionally caused marginal visual conditions, but were largely non-factors in flight missions **(Figs. 6 & 8)**. The majority of survey east of the Cascades had been completed prior to the development of large-scale wildfires. The regular season ADS concluded mid-September with flights over Bellingham and the San Juan Islands, the Cascades east of Seattle, and the Blue Mountains. This was an ideal time to wrap up flight operations in western Washington, as smoke from the Bolt Creek and Goat Rock fires began to blanket Puget Sound and the surrounding areas **(Figs. 6 & 9)**. Forests in this area are often reserved for end-of-season flights, and could have been compromised if the fires nearby were more established at the time. For a detailed description of the methods aerial surveyors use, see the "Aerial Detection Survey Methodology" section on page 56.

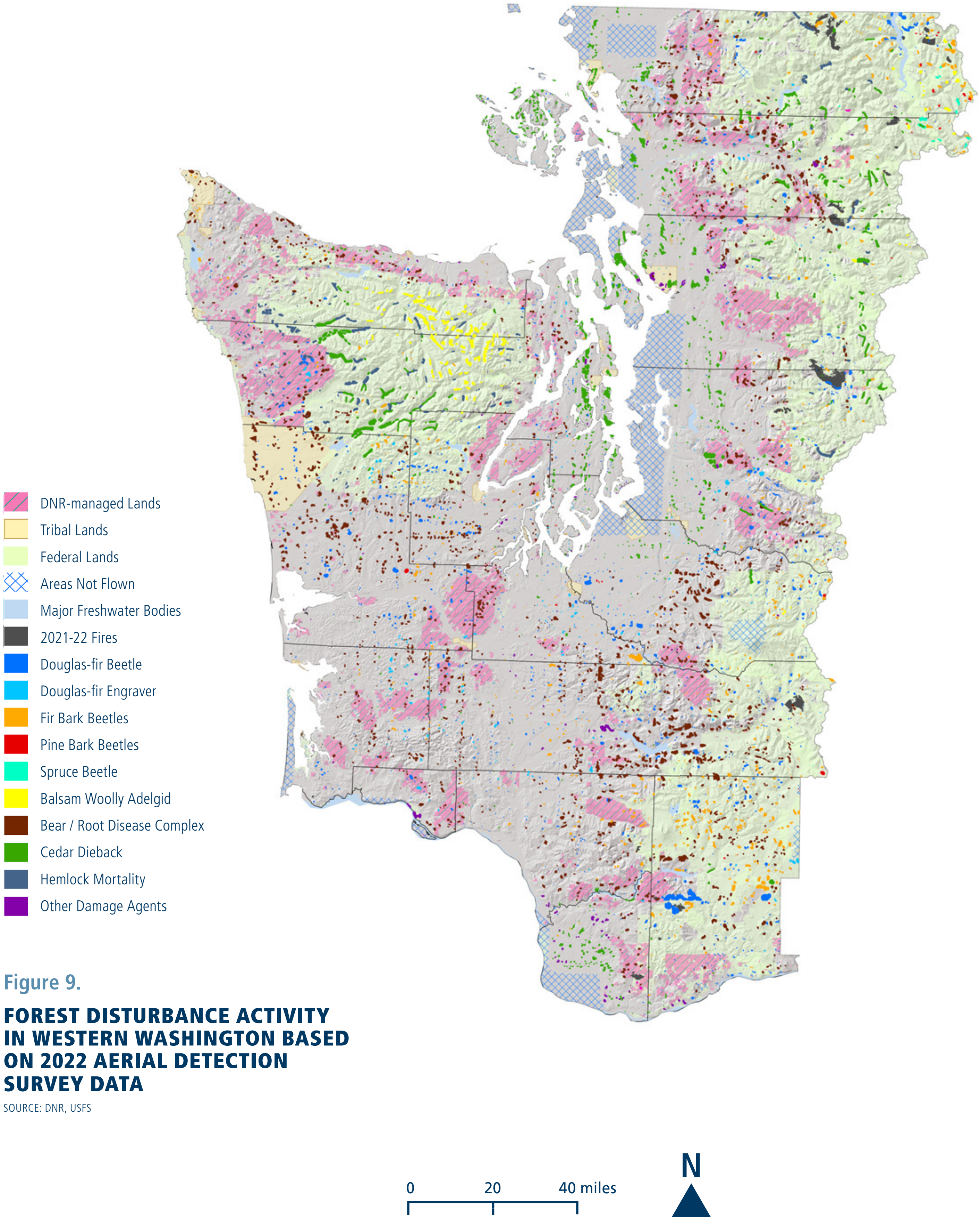


Figure 9.

FOREST DISTURBANCE ACTIVITY IN WESTERN WASHINGTON BASED ON 2022 AERIAL DETECTION SURVEY DATA

SOURCE: DNR, USFS

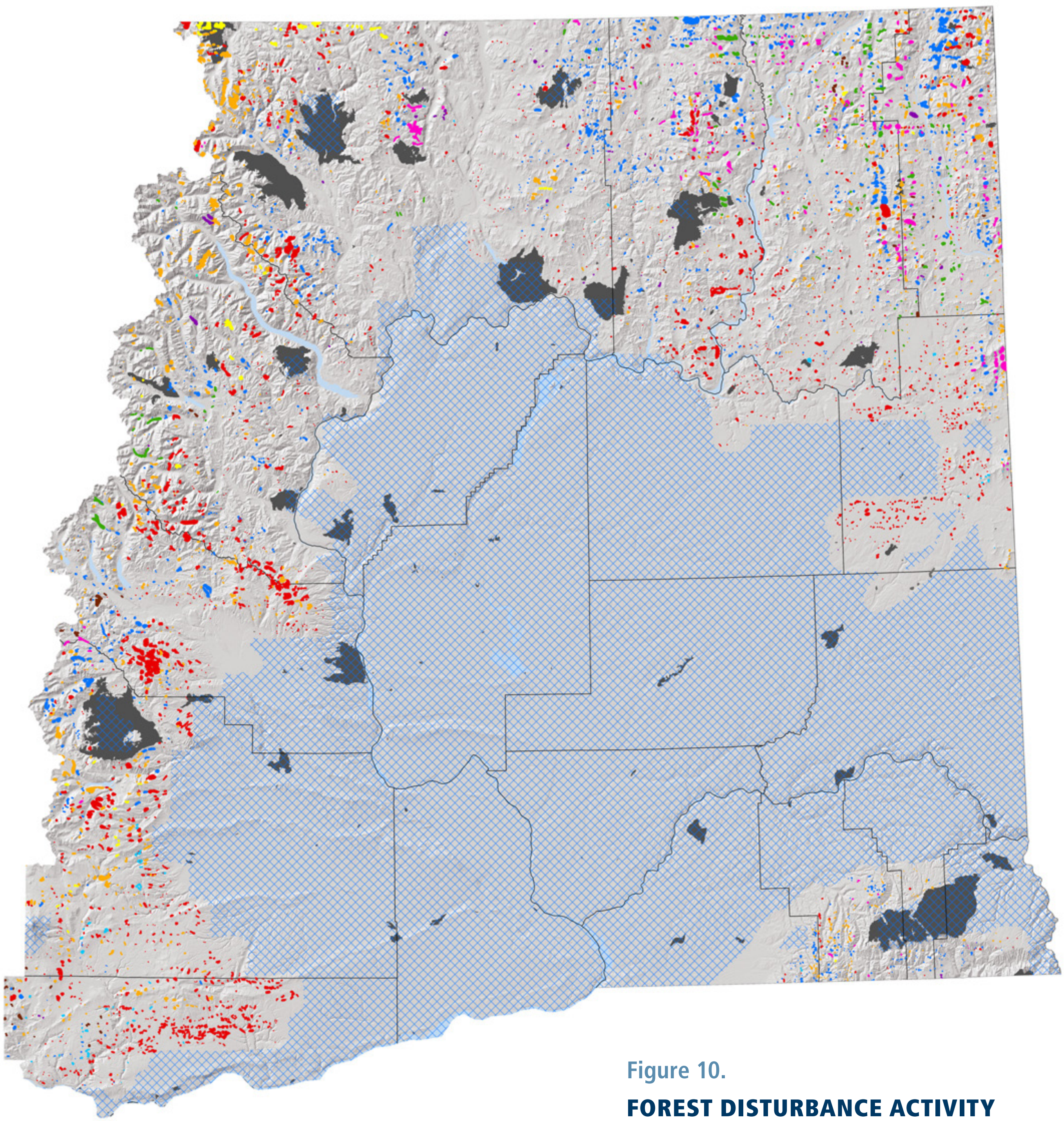


Figure 10.

FOREST DISTURBANCE ACTIVITY IN EASTERN WASHINGTON BASED ON 2022 AERIAL DETECTION SURVEY DATA

SOURCE: DNR, USFS

MELISSA FISCHER / USDA FOREST SERVICE

Western gall rust caused by *Endocronartium harknessii* (formerly *Peridermium harknessii*) on pine.

Biotic Disturbances Influencing Forest Health

Biotic disturbances — disturbances caused by living agents — such as insects, fungi, animals, and parasitic dwarf mistletoe plants can influence forest health directly by causing mortality or chronic declines in tree health. Damage from these agents can also have an indirect influence on forest health by weakening trees and predisposing them to attack by other pests that may be more damaging or lethal. Unlike abiotic disturbances such as drought and wildfire, forest insects and pathogens typically attack a specific host tree species or narrow range of hosts, so damage may be limited in mixed-species forests. At low levels, native insects and pathogens provide important ecological roles in nutrient cycling of dead plant material and removal of weak, suppressed, and unthrifty trees, thus leaving healthier trees with better access to water, light, and nutrients. At high levels, outbreak populations can cause significant changes in stand structure and composition over time. Non-native or invasive forest insects and diseases, such as spongy moth (formerly known as gypsy moth) and sudden oak death, are major threats to Washington's forests, because native trees do not have effective defense mechanisms.

The following section is a summary of recent forest insect and disease damage trends and conditions collected through a combination of aerial surveys, remote sensing, pheromone trapping, stream baiting, field observations, and ground monitoring plots.

INSECTS | BARK BEETLES


GLENN KOHLER / DNR

Pine Bark Beetles

(*Dendroctonus ponderosae* Hopkins,
Dendroctonus brevicomis LeConte & *Ips* spp.)

NATIVE

The area with mortality caused by pine bark beetles in 2022 was approximately 123,700 acres, close to the ten-year average of 123,900 acres **(Fig. 11)**. Data for 2020 are not included in this calculation due to changes in survey methods and reduced survey area. Relative to 2021, pine bark beetle caused mortality increased in all pine host species **(Table 1)**.

Mountain pine beetle *Dendroctonus ponderosae* damage increased from 53,100 acres in 2021 to approximately 76,800 acres in 2022. The majority of pine bark beetle mortality recorded each year is in lodgepole pine killed by mountain pine beetle (MPB), which killed 66,800 acres of lodgepole pine in 2022. Recent totals of MPB-killed lodgepole pines included 51,300 acres in 2021 and 76,500 acres in 2019.

In 2022, the highest concentrations of MPB mortality in lodgepole were mapped: north of Mt. Adams in Yakima County; around the Goat Rocks Wilderness area; in the Manastash Ridge area of southwest Kittitas County; along the Kittitas-Chelan county border; in western Okanogan County around the Lake Chelan-Sawtooth Wilderness area and the Pasayten Wilderness area; in the Sherman Pass area of Ferry County; and in northern Pend Oreille County.

MPB-caused mortality in ponderosa pine was mapped on 4,800 acres in 2022, below the 10-year average of about 18,000 acres. Observers recorded 5,100 acres with MPB-caused mortality of whitebark pine in 2022, the highest level since 2011 (5,700 acres). Areas with high concentrations of whitebark pine mortality included the upper Ahtanum in Yakima County, around the Manastash Ridge area of southwest Kittitas County, around the Alpine Lakes Wilderness west of Leavenworth, and in western Okanogan County north of Mazama. Fewer than 200 acres with western white pine mortality were mapped in 2022. Some mortality in whitebark pine and western white pine may be due to non-native white pine blister rust disease directly killing trees or predisposing infected trees to attack by MPB.

MORTALITY OF PONDEROSA PINE DUE TO WESTERN PINE BEETLE HAS INCREASED STEADILY SINCE 2012. IT REACHED A PEAK OF APPROXIMATELY 44,300 ACRES IN 2022, UP FROM 37,800 ACRES IN 2021.

Mortality of ponderosa pine due to western pine beetle *Dendroctonus brevicomis* has increased steadily since 2012. It reached a peak of approximately 44,300 acres in 2022, up from 37,800 acres in 2021, more than twice the affected area observed in 2017 and 2018, and the highest level recorded since 2006 **(Fig. 12)**. Western pine beetle (WPB) damage has been widely reported throughout eastern Washington, and DNR staff have observed a notable increase in requests for information from landowners and land managers. Recent drought conditions are likely an important driver of these increases. The highest concentrations of WPB-caused mortality were throughout forested areas of Klickitat County and the Yakama Indian Reservation, central Kittitas County, eastern Okanogan County, the Confederated Tribes of the Colville Reservation, throughout Stevens and Spokane counties, and the Blue Mountains in southeast Washington.

Pine mortality attributed to Ips pine engravers (*Ips* species) was mapped on approximately 2,500 acres in 2022, an increase from the 1,500 acres mapped in 2021 and above the 10-year average of 1,700 acres. Ponderosa pine was the most common species affected. Some of the same areas are also experiencing WPB outbreaks, which have a very similar aerial survey damage signature in young ponderosa pines. The highest concentrations of mortality were in Spokane, southern Stevens, eastern Okanogan, Klickitat and Yakima counties.

GLENN KOHLER / DNR

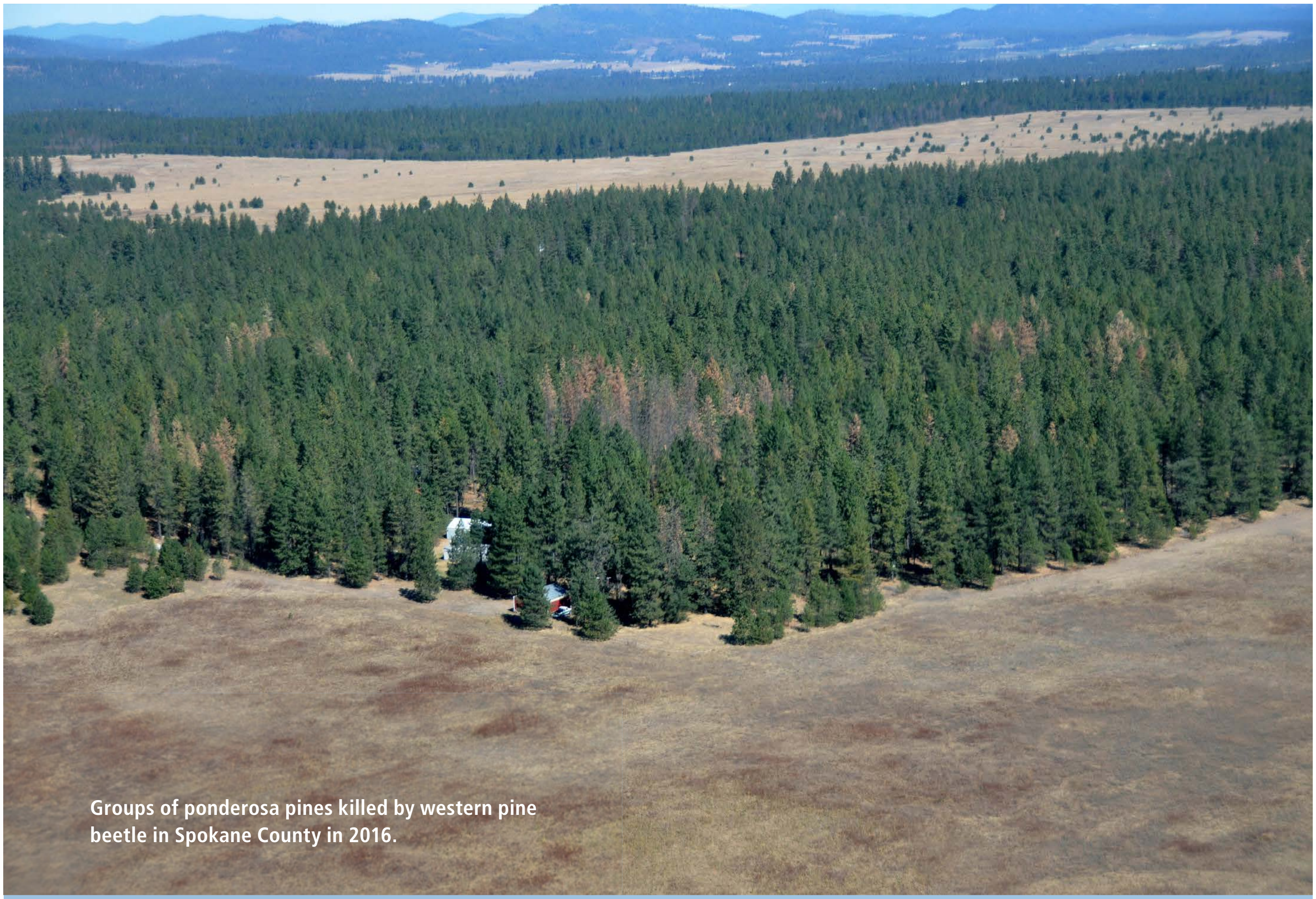
Western white pine killed by mountain pine beetle in the central Washington Cascades in 2020.

Table 1.

ACRES OBSERVED IN AERIAL DETECTION SURVEY WITH PINE BARK BEETLE DAMAGE IN WASHINGTON

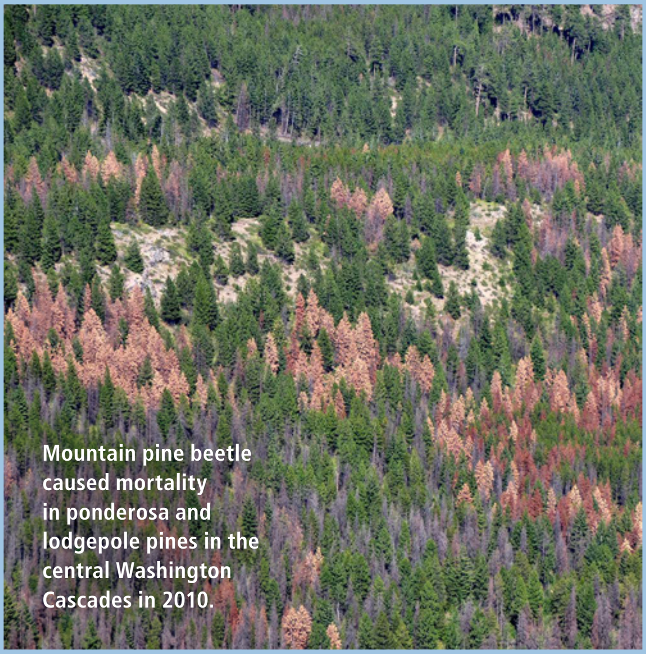
BEETLE SPECIES	HOST(S)	2021 ACRES WITH MORTALITY	2022 ACRES WITH MORTALITY
Mountain Pine Beetle	Lodgepole Pine	51,300	66,800
Mountain Pine Beetle	Ponderosa Pine	750	4,800
Mountain Pine Beetle	Whitebark Pine	1,100	5,100
Mountain Pine Beetle	Western White Pine	10	160
Western Pine Beetle	Ponderosa Pine	37,800	44,300
Pine Engravers (*Ips* species)	All Pines	1,500	2,500
Totals		92,460	123,660

GLENN KOHLER / DNR



Groups of ponderosa pines killed by western pine beetle in Spokane County in 2016.

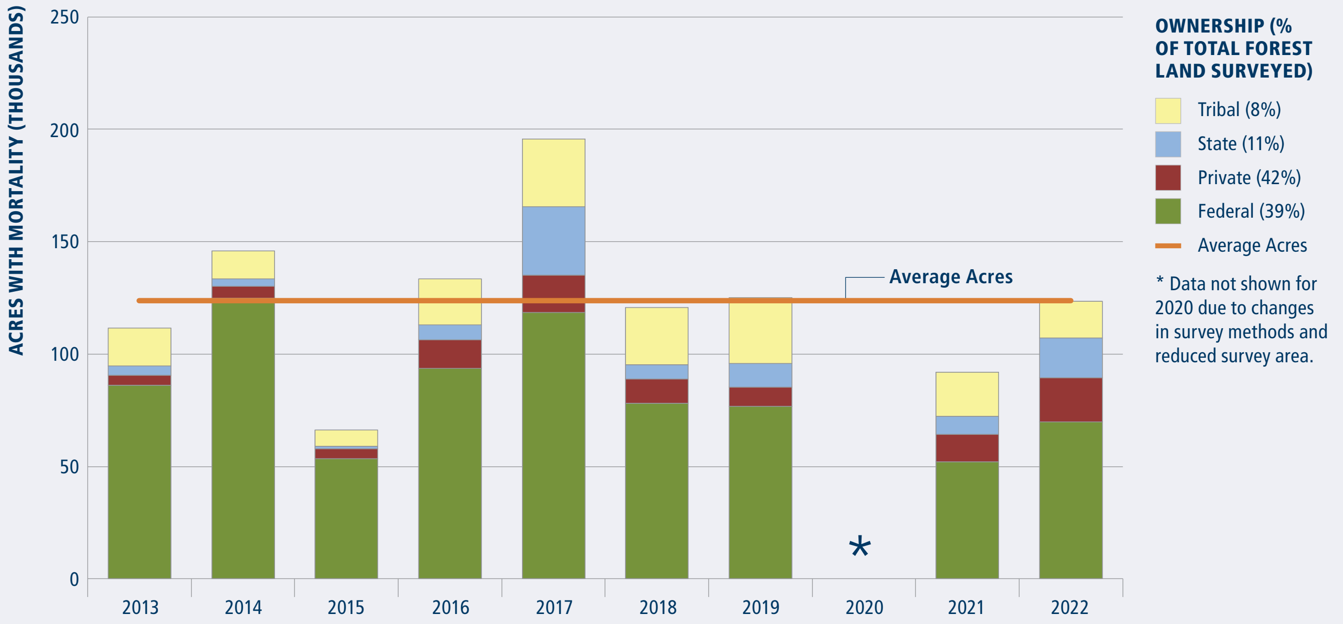
AMY RAMSEY / DNR



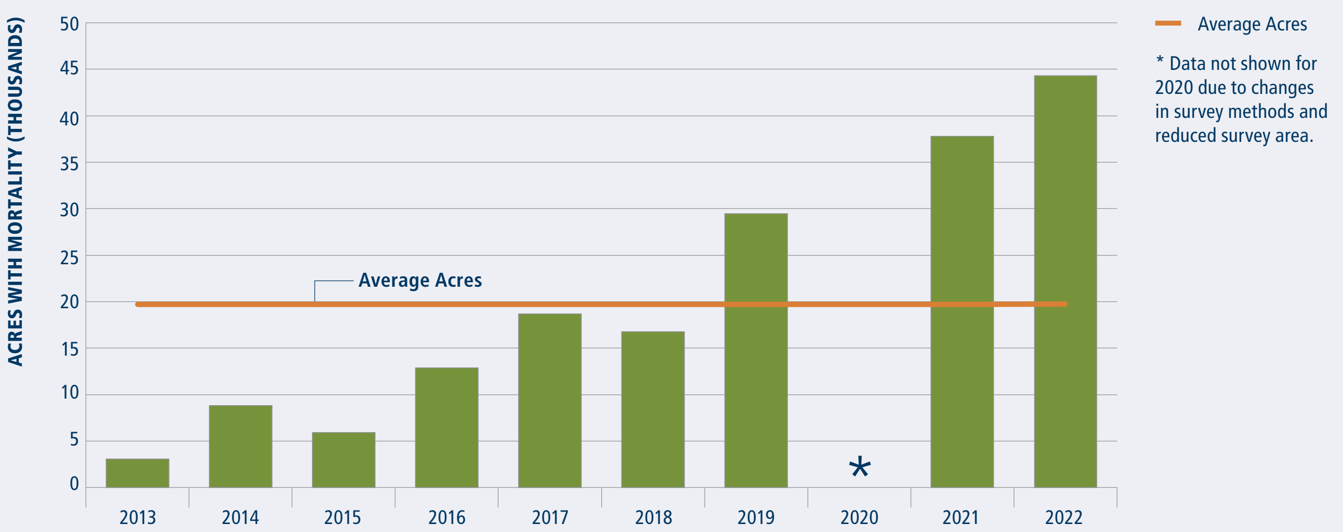
Mountain pine beetle caused mortality in ponderosa and lodgepole pines in the central Washington Cascades in 2010.

DNR STAFF HAVE OBSERVED A NOTABLE INCREASE IN REQUESTS FOR INFORMATION FROM LANDOWNERS AND LAND MANAGERS. RECENT DROUGHT CONDITIONS ARE LIKELY AN IMPORTANT DRIVER OF THESE INCREASES.

PINE BARK BEETLES 10-YEAR TREND FOR TOTAL ACRES AFFECTED IN WASHINGTON Figure 11.



WESTERN PINE BEETLE 10-YEAR TREND FOR TOTAL ACRES AFFECTED IN WASHINGTON Figure 12.



INSECTS | BARK BEETLES

GLENN KOHLER / DNR

Douglas-fir Beetle

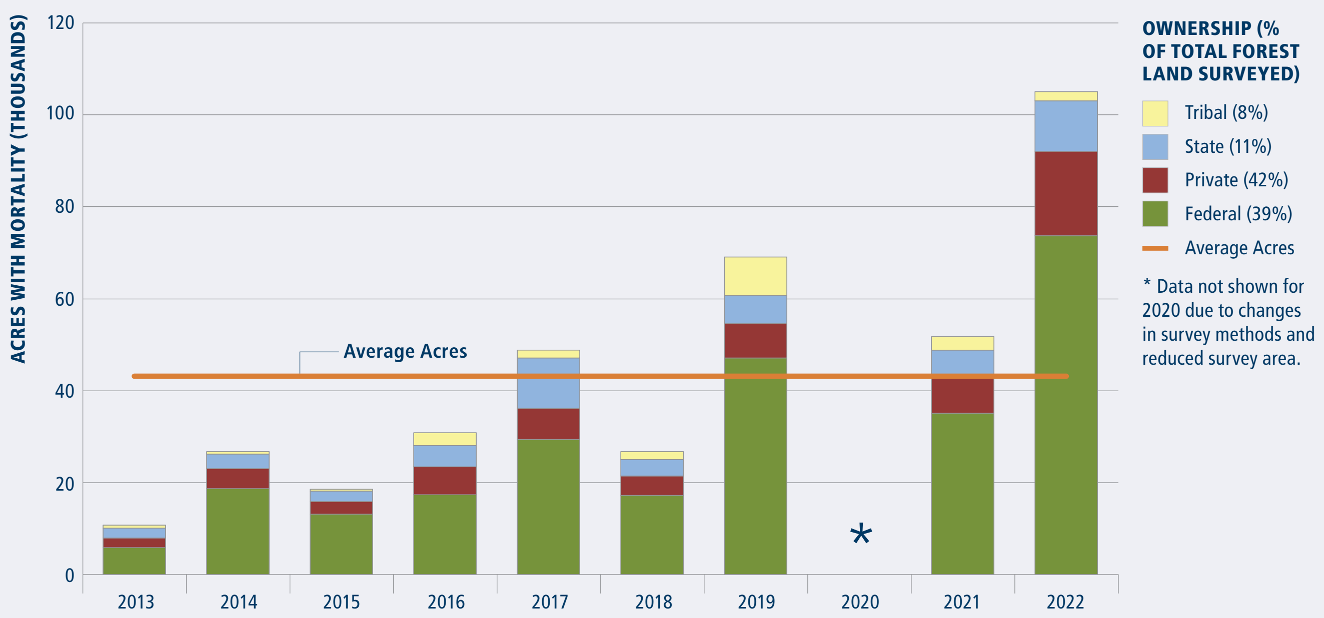
(*Dendroctonus pseudotsugae* Hopkins)

NATIVE

Mortality due to Douglas-fir beetle (DFB) has been increasing in recent years, reaching approximately 105,000 acres in 2022, well above the 10-year average of 43,000 acres, and the highest level recorded since 2001 **(Fig. 13)**. Scattered areas of DFB-caused mortality were detected throughout western Washington, with higher concentrations in Skamania, Lewis, Pierce, King, Whatcom, Jefferson, Grays Harbor, Pacific, and Mason counties. Most of the increase in DFB damage appears to be in eastern Washington, where the highest concentrations were in northwest Yakima and western Kittitas counties, mountainous areas of Okanogan County, throughout Ferry, Stevens, and Pend Oreille counties, and the Blue Mountains in southeast Washington.

The aerial survey signature used for DFB is typically distinct groupings of mature Douglas-fir with bright orange-colored crowns **(Fig. 14)**. In northeast Washington, areas mapped as DFB in 2022 appeared more diffuse and scattered, more brown-orange in color, and with less retained foliage **(Fig. 15)**. Limited ground checks indicate that Douglas-firs in some of these areas may have been killed by flatheaded fir borer (*Phaenops drummondi*) or secondary bark beetles. Both types of beetles are known to attack trees stressed by drought or growing on drought-stressed sites. Ground checks will be conducted in 2023 to improve accuracy of aerial survey damage agent codes used for this type of damage.

DOUGLAS-FIR BEETLE 10-YEAR TREND FOR TOTAL ACRES AFFECTED IN WASHINGTON
Figure 13.



DANIEL MILLER / USDA FOREST SERVICE, BUGWOOD.ORG

Figure 14. Douglas fir mortality group kill pattern.

ISAAC DAVIS / DNR

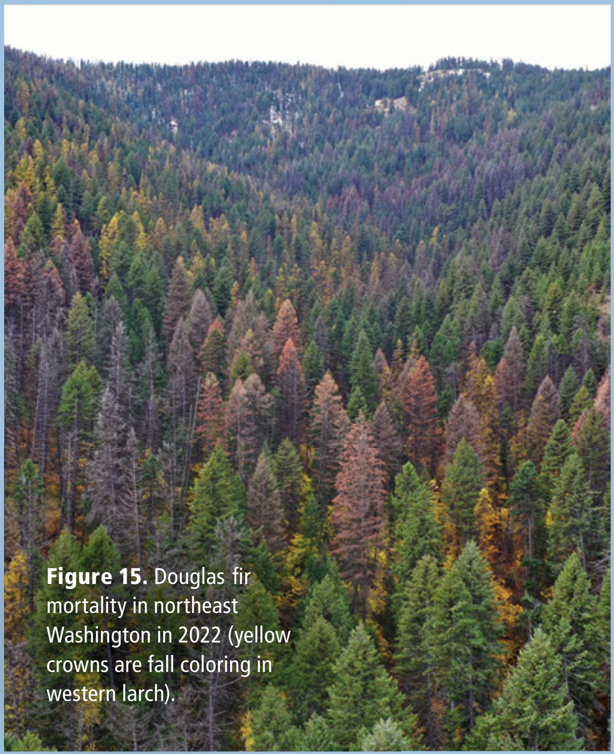


Figure 15. Douglas fir mortality in northeast Washington in 2022 (yellow crowns are fall coloring in western larch).

MOST OF THE INCREASE IN DOUGLAS-FIR BEETLE DAMAGE APPEARS TO BE IN EASTERN WASHINGTON.

INSECTS | BARK BEETLES

Secondary Bark Beetles in Douglas-fir

(*Scolytus monticolae* (Swaine), *Scolytus unispinosus* LeConte, and *Pseudohylesinus nebulosus* (LeConte))

NATIVE

The aerial survey damage signature of dead tops and branch flagging in Douglas-fir is attributed to Douglas-fir engraver (*Scolytus unispinosus*). However, this type of damage is also caused by two other secondary bark beetle species: Douglas-fir pole beetle (*Pseudohylesinus nebulosus*) and *Scolytus monticolae*. This group of bark beetles is "secondary" because they are not typically the primary killers of healthy trees, but tend to attack trees stressed by other factors, primarily drought, when given the opportunity. All three species can infest the same tree and are difficult to distinguish based on their egg and larval galleries alone.

The amount of Douglas-fir engraver damage mapped in 2022 was approximately 9,400 acres, a slight increase from the 8,100 acres in 2021, and above the 10-year average of 5,200 acres. The highest concentrations of damage in western Washington were in Grays Harbor County, Pacific County, Thurston County, and in Cascade foothills areas of Skamania, Pierce, King, and Skagit counties.

In eastern Washington, the highest concentrations of damage were in western Klickitat and Yakima counties. Levels were lower in northeast Washington; however, Douglas-fir engraver activity may have contributed to unusual damage signatures observed in Douglas-fir that were mapped as Douglas-fir beetle (see Douglas-fir beetle section). Ground checks will be conducted in 2023 to improve accuracy of aerial survey damage agent codes used for this type of damage.

Attacks by these species usually occur in small diameter Douglas-fir trees, or the tops and branches of larger trees, resulting in a patchy pattern of dieback in mature Douglas-fir tree crowns. Secondary bark beetle species do not typically cause mortality, particularly in mature trees. Stressors such as drought and root disease may predispose Douglas-fir to attack by these species. Attacks during drought are more likely to be successful and cause mortality.

MELISSA FISCHER / USDA FOREST SERVICE

Damage to Douglas fir from secondary bark beetles in northeast Washington in 2018 .

THIS GROUP OF BARK BEETLES IS "SECONDARY" BECAUSE THEY ARE NOT TYPICALLY THE PRIMARY KILLERS OF HEALTHY TREES, BUT TEND TO ATTACK TREES STRESSED BY OTHER FACTORS, PRIMARILY DROUGHT, WHEN GIVEN THE OPPORTUNITY.

MELISSA FISCHER / USDA FOREST SERVICE

Secondary bark beetle larval galleries in Douglas fir.

BEN SMITH / USDA FOREST SERVICE

Spruce beetle caused Engelmann spruce mortality in Okanogan County in 2012.

INSECTS | BARK BEETLES

DAVID MCCOMB / USDA
FOREST SERVICE, BUGWOOD.ORG

Spruce Beetle

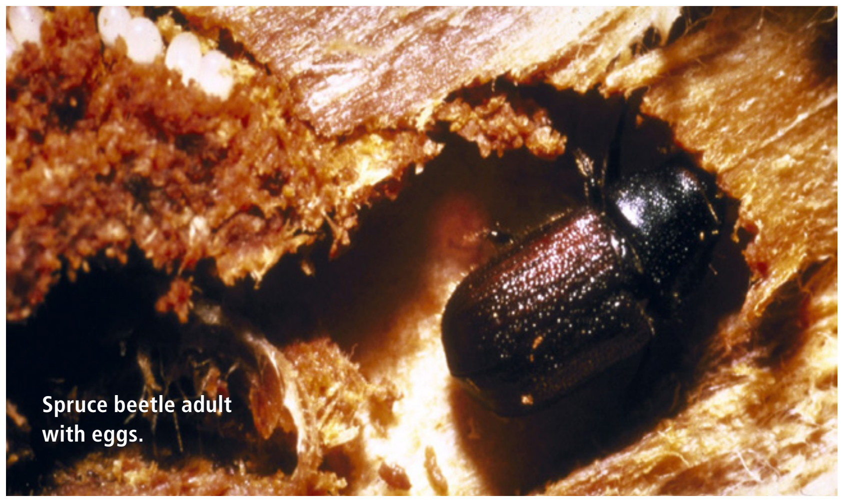
(*Dendroctonus rufipennis* Kirby)

NATIVE

The area affected by spruce beetle in Engelmann spruce in 2022 was approximately 1,900 acres, an increase from the 1,400 acres mapped in 2021, and well below the 10-year average of 15,200 acres **(Fig. 16)**.

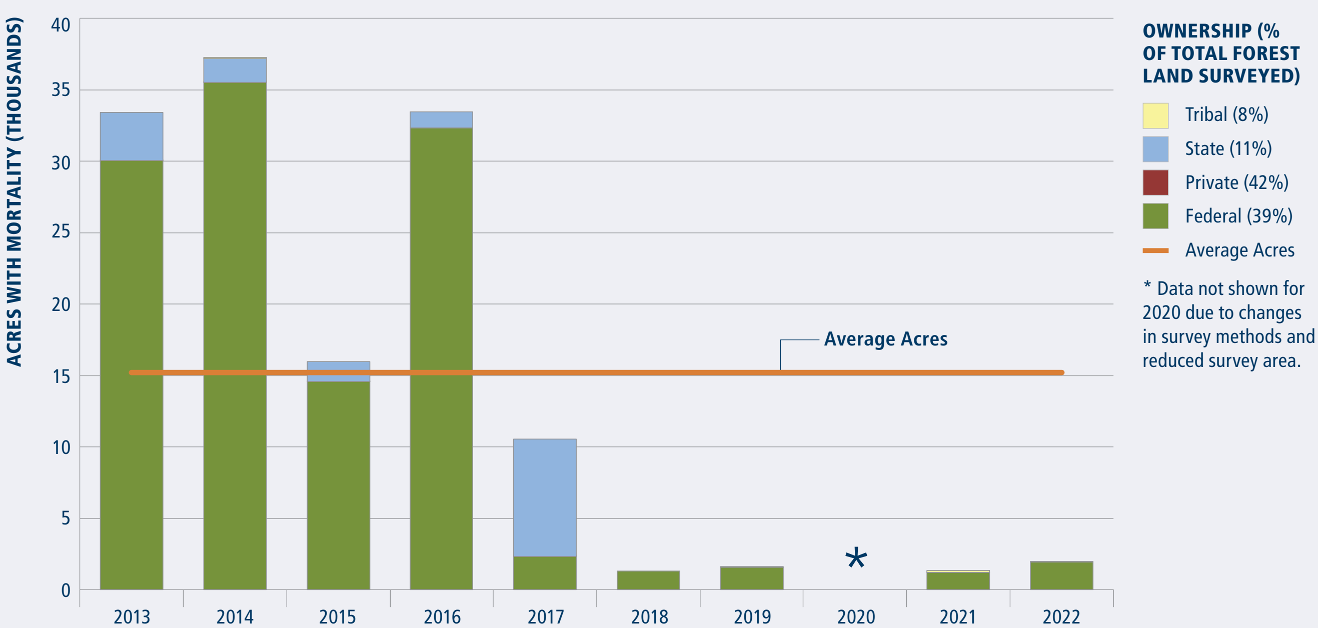
The affected area is along the Cascade crest around the Pasayten Wilderness area in Okanogan, Whatcom, and Skagit counties. This area experienced a large outbreak until 2017, with a peak of over 60,000 acres with mortality in 2012. Low levels of spruce beetle activity have persisted in this area since 2018.

EDWARD H. HOLSTEN / USDA FOREST SERVICE, BUGWOOD.ORG



Spruce beetle adult with eggs.

SPRUCE BEETLE 10-YEAR TREND FOR TOTAL ACRES AFFECTED IN WASHINGTON Figure 16.



INSECTS | BARK BEETLES

DONALD OWEN, CALIFORNIA DEPARTMENT OF FORESTRY AND FIRE PROTECTION, BUGWOOD.ORG

Fir Engraver

(*Scolytus ventralis* LeConte)

NATIVE

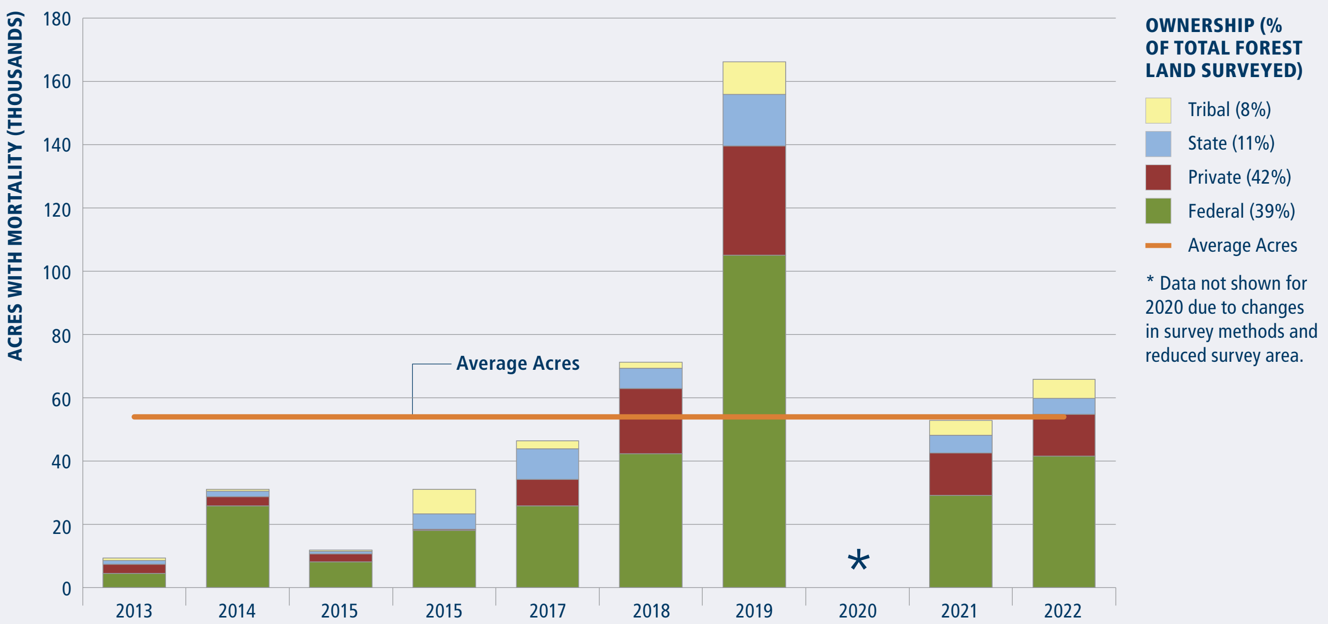
The fir engraver beetle can attack all species of true fir (*Abies*) in Washington, but the primary hosts in Washington are grand fir and noble fir. Fir engraver-caused mortality, primarily in grand fir, has been steadily increasing since 2015, and reached a 10-year high of 166,300 acres in 2019, more than twice the area recorded in 2018 **(Fig. 17)**. The total area with mortality decreased to 52,500 acres in 2021, then increased to approximately 65,700 acres in 2022.

In eastern Washington, the moderate increase of fir engraver activity in 2022 was not as dramatic as the significant increase in mortality of true fir observed in eastern Oregon. The most concentrated areas of mortality were throughout the Cascade Mountains areas of Klickitat, Yakima, Kittitas, and Chelan counties and in the Kettle River Range and Selkirk Mountains in Ferry, Stevens, and Pend Oreille counties. West of the Cascades, concentrated areas of damage were recorded in Skamania, Cowlitz, Lewis, King, Skagit, and Whatcom counties.

MELISSA FISCHER / USDA FOREST SERVICE

Fir engraver beetle galleries.

FIR ENGRAVER 10-YEAR TREND FOR TOTAL ACRES AFFECTED IN WASHINGTON Figure 17.



INSECTS | BARK BEETLES

STEVEN VALLEY / OREGON DEPARTMENT OF AGRICULTURE, BUGWOOD.ORG

Silver Fir Beetle

(*Pseudohylesinus sericeus* (Mannerheim))

NATIVE

The silver fir beetle and a related species, the fir root bark beetle (*Pseudohylesinus granulatus*), can kill true firs (*Abies*) and other conifer hosts in Washington such as western hemlock and Douglas-fir. The most commonly damaged host is Pacific silver fir. In a typical year, mortality is scattered and attacks are focused on trees weakened by disease or attacks by other fir bark beetles. Outbreaks are rare, but increases in population can occur following windthrow events that generate abundant breeding material.

In Washington, observers mapped 1,100 acres in Washington with mortality caused by silver fir beetle (SFB) in 2022, up from the 800 acres mapped in 2021. The highest level of SFB recorded by aerial survey in recent decades was 6,400 acres in 2004. Very low amounts of mortality were recorded from 2005 until 2015 when levels began increasing to a recent peak of 1,700 acres in 2019. Small areas with mortality were mapped in 2022 near in North Cascades National Park and Glacier Peak Wilderness Area in Chelan County.

SUBALPINE FIR MORTALITY HAS BEEN INCREASING SINCE 2015, REACHING A RECENT PEAK OF 49,900 ACRES WITH DAMAGE IN 2021.

INSECTS | BARK BEETLES

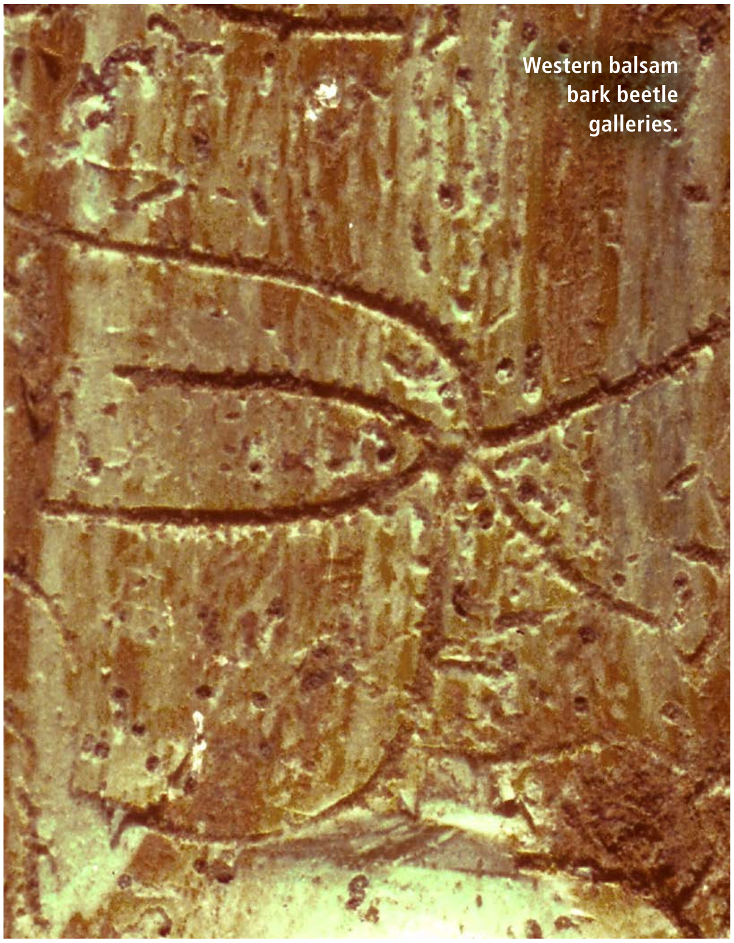
USDA FOREST SERVICE - REGION 2 ROCKY MOUNTAIN REGION, USDA FOREST SERVICE, BUGWOOD.ORG

Western Balsam Bark Beetle

(*Dryocoetes confusus* Swaine)

NATIVE

Western balsam bark beetle (WBBB), often in conjunction with balsam woolly adelgid, is an important driver of subalpine fir mortality in high-elevation Washington forests. Observers mapped 39,400 acres with WBBB-caused mortality in 2022. Subalpine fir mortality has been increasing since 2015, reaching a recent peak of 49,900 acres with damage in 2021, the highest level since 2007. The most concentrated areas with damage were along the Cascade crest in western Okanogan County, north Chelan County, eastern Whatcom and Skagit counties, and northwest Yakima County. Areas affected in northeast Washington were throughout high elevations in the Colville National Forest in Ferry, Stevens, and Pend Oreille counties.



SCOTT TUNNOCK / USDA FOREST SERVICE, BUGWOOD.ORG

Western balsam bark beetle galleries.

INSECTS | DEFOLIATORS

GLENN KOHLER /DNR

Douglas-fir Tussock Moth

(*Orgyia pseudotsugata* McDunnough)

NATIVE

GLENN KOHLER /DNR

Douglas fir defoliated by Douglas fir tussock moth in Okanogan County in 2019

No Douglas-fir tussock moth (DFTM) defoliation was recorded in Washington in 2022. The most recent outbreak in Kittitas and Chelan counties defoliated 1,900 acres in 2018 and 5,600 acres in 2019. The damage was severe in some areas along US Highway 97 (Blewett Pass) and small patches south of Interstate 90 west of Ellensburg, resulting in mortality of Douglas-fir and grand fir hosts. A smaller outbreak in 2019 resulted in approximately 600 acres with defoliation east of the Okanogan River between Oroville and Chesaw in Okanogan County.

Established over 40 years ago, the interagency network of "Early Warning System" pheromone traps at approximately 240 locations in eastern Washington continues to be monitored annually **(Fig. 18)**. The Early Warning System is a pheromone-based trapping system used to detect outbreaks of Douglas-fir tussock moth in the western United States. Each year, forest health specialists set out sticky traps baited with a synthetic version of the pheromone produced by female moths to attract male moths. These traps are retrieved after the male flight period, and the number of male DFTM moths is recorded. Increases in trap catch numbers may indicate outbreak events in the following years **(Fig. 19)**.

Trap catches at several sites in Okanogan County east of Oroville and in the Methow Valley remain higher than typical in non-outbreak years. DFTM defoliation has not been recorded in these areas since 2019. DFTM defoliation in these areas is possible in 2023, but not likely, given virus load and absence of defoliation in 2022. High trap-catch numbers do not always correlate with the exact location of future defoliation, and high numbers can be associated with declining outbreak events. Outbreaks of DFTM in the Pacific Northwest are cyclical and occur approximately every seven to ten years from the first year with defoliation during the previous outbreak **(Fig. 19)**. For more information on the Early Warning System, go to: https://www.fs.usda.gov/detail/r6/forest-grasslandhealth/?cid=fsbdev2_027373

INSECTS | DEFOLIATORS

DOUGLAS-FIR TUSSOCK MOTH TRAP CATCHES AND DEFOLIATION IN WASHINGTON 1986-2022 Figure 19.

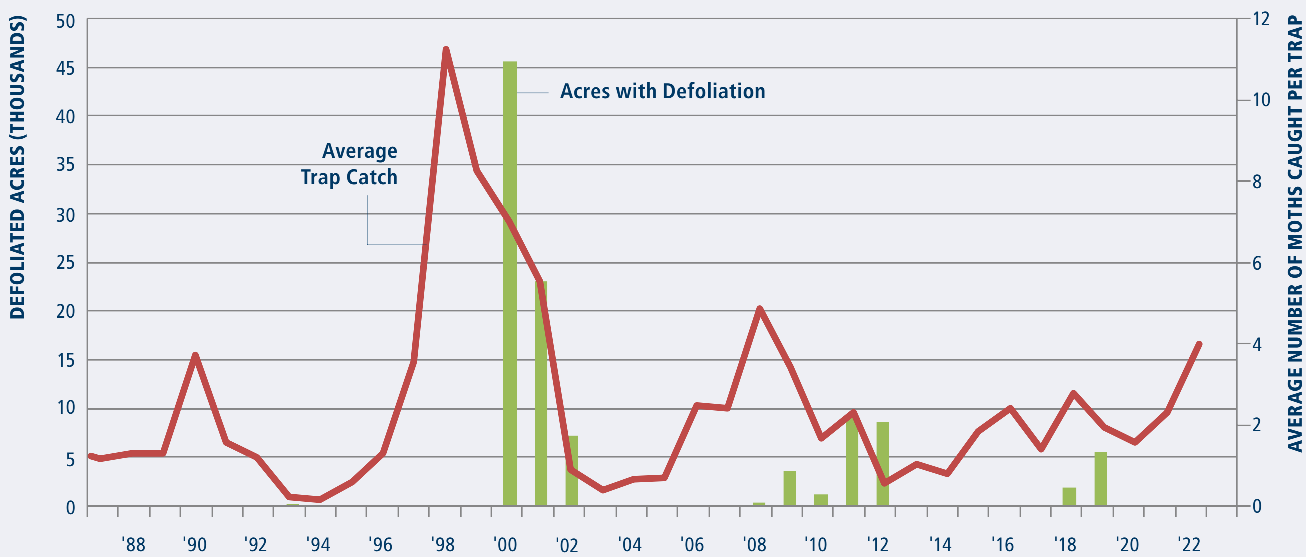


Figure 18.

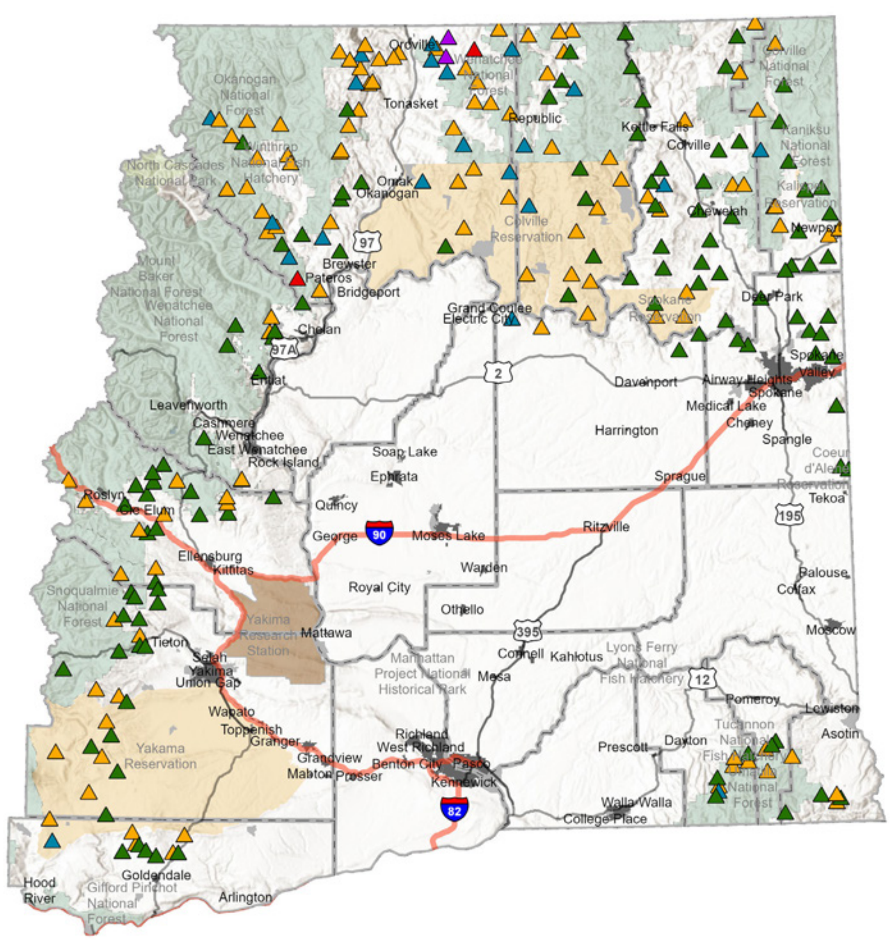
DOUGLAS-FIR TUSSOCK MOTH PHEROMONE TRAP CATCH RESULTS IN EASTERN WASHINGTON 2022

SOURCE: USFS

- 0 Moths
- 1 to 10
- 11 to 25
- 26 to 40
- More Than 40

N

40 miles



INSECTS | DEFOLIATORS

GLENN KOHLER /DNR

Western Spruce Budworm

(*Choristoneura freemani* Razowski)

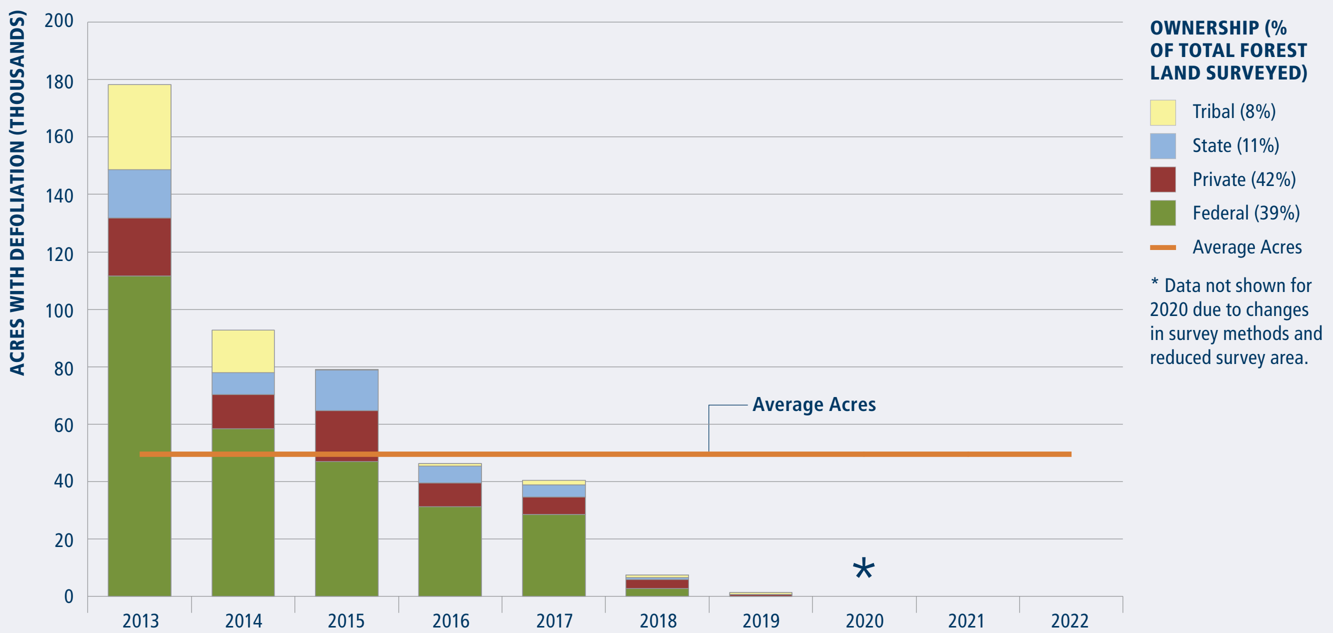
NATIVE

The total acres with western spruce budworm (WSB) defoliation in Washington has steadily declined from peak levels over 500,000 acres in 2011 and 2012 down to no detectable damage mapped from the air in 2021 and 2022 **(Fig. 20)**. The last major outbreak in the central Washington Cascades that lasted over a decade had declined by 2017. A shorter-lived and smaller outbreak in northeast Washington appears to have also declined with a large reduction of defoliated acres in 2019. WSB pheromone traps were placed at 109 locations in northeast Washington in 2022 **(Fig. 21)**. Only a few trap sites in northeast Okanogan County indicated the potential for moderate defoliation in 2023. Trap catches elsewhere remain low. They do not predict defoliation occurring in 2023.

MIKE JOHNSON / USDA FOREST SERVICE

Western spruce budworm larva.

WESTERN SPRUCE BUDWORM 10-YEAR TREND FOR TOTAL ACRES AFFECTED IN WASHINGTON Figure 20.



INSECTS | DEFOLIATORS

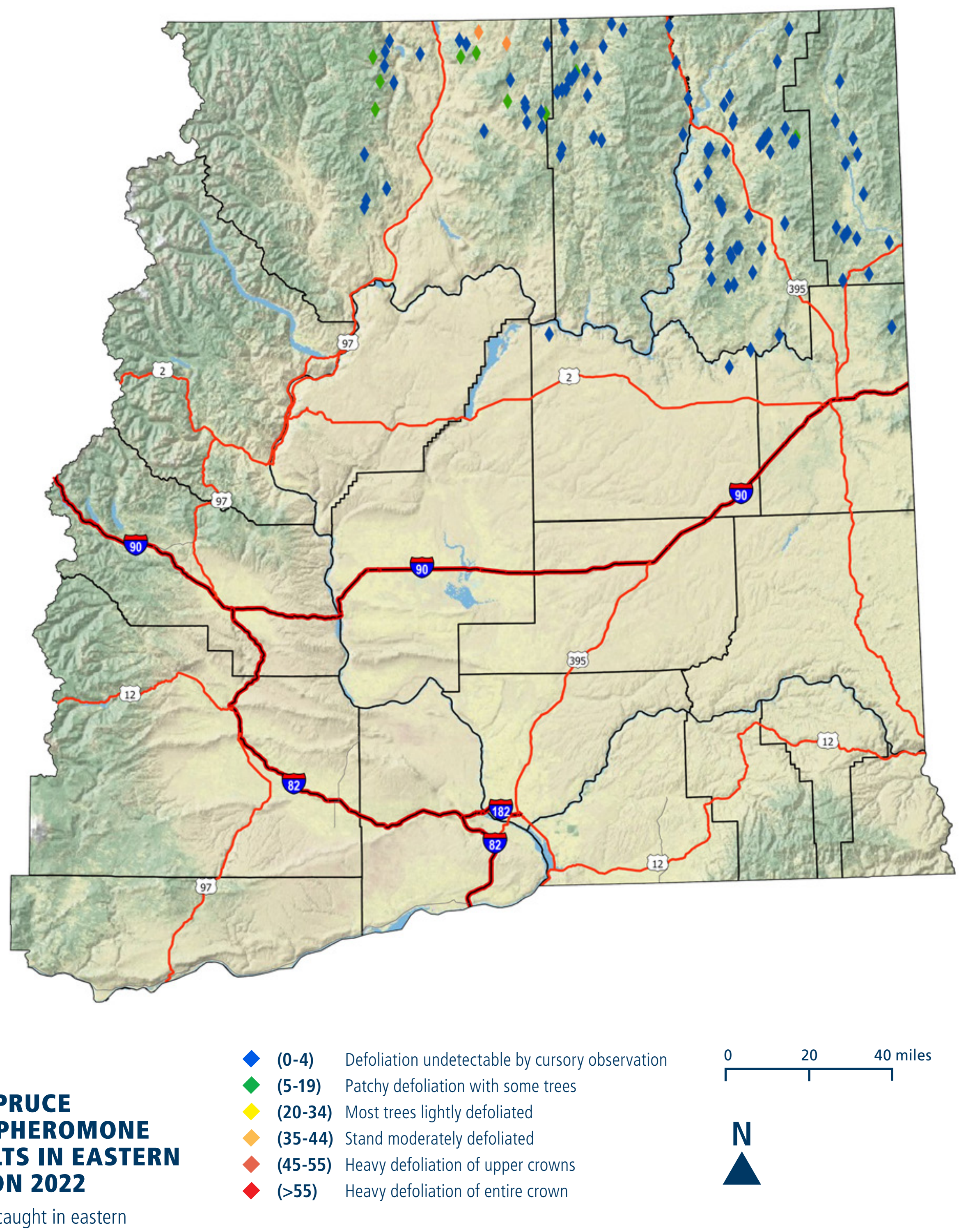


Figure 21.

WESTERN SPRUCE BUDWORM PHEROMONE TRAP RESULTS IN EASTERN WASHINGTON 2022

Number of moths caught in eastern Washington for 2022 and expected 2023 defoliation.

SOURCE: DNR, USFS

INSECTS | DEFOLIATORS

JON YUSCHOCK / BUGWOOD.ORG

Spongy Moth

(*Lymantria dispar* Linnaeus)

NON-NATIVE

On December 14, 2022, USDA's Animal and Plant Health Inspection Service (APHIS) announced it has replaced the common name for the Asian gypsy moth complex (*L. dispar asiatica, L. dispar japonica, L. albescens, L. postalba, and L. umbrosa*). This name change is in alignment with the recent selection of spongy moth for *Lymantria dispar* by the Entomological Society of America's "Better Common Names Project" in March of 2022. The new common name "flighted spongy moth complex" for this group highlights the unifying characteristic that poses the greatest management threat of these closely related species.

The Washington State Department of Agriculture (WSDA) did not conduct an aerial eradication project for spongy moth in 2022. Mass trapping was determined to be the best approach for a flighted spongy moth (*Lymantria dispar asiatica*) detection in the Kettle Falls area in 2021. Approximately 145 traps were deployed in a 20-acre area surrounding the detection site. Traps were monitored weekly during the anticipated adult flight period – no additional moths were detected in this area. High-density, precision delimitation trapping will continue in this area for two years to ensure there are no reproducing populations present.

WSDA staff deployed approximately 15,500 detection traps for *Lymantria dispar* in 2022. The pheromone traps target both the spongy moth and the flighted spongy moth species. Thirty adult male moths were collected in King (8), Snohomish (8), Whatcom (3), Pierce (3), San Juan (3), Skagit (3), Thurston (1), and Kitsap (1) counties. All moths underwent molecular analysis and were determined to be *L. dispar dispar*. High-density delimitation trapping will surround each detection site in 2023 to determine the extent of a possible spongy moth infestation. No eradication projects are planned for the spring of 2023.

More information about spongy moth in Washington State can be found at www.agr.wa.gov/moths.

Spongy moth larva.

JOHN GHENT / BUGWOOD.ORG

WASHINGTON STATE DEPARTMENT OF AGRICULTURE STAFF DEPLOYED APPROXIMATELY 15,500 DETECTION TRAPS FOR *LYMANTRIA DISPAR* IN 2022.

INSECTS | BRANCH AND TERMINAL INSECTS

GILLES SAN MARTIN

Balsam Woolly Adelgid

(*Adelges piceae* Ratzeburg)

NON-NATIVE

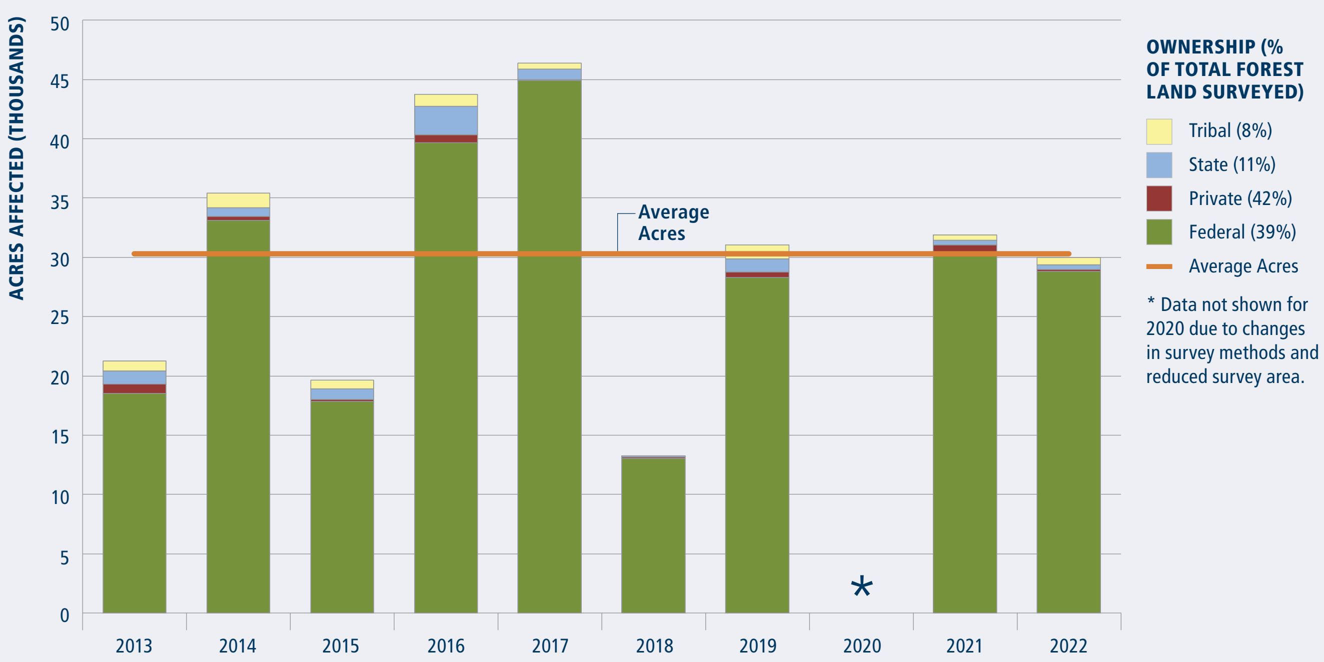
DARCI DICKINSON / USDA FOREST SERVICE

Balsam woolly adelgid (BWA) is a non-native sucking insect that continues to be widespread in Washington and cause mortality to subalpine fir, Pacific silver fir, and grand fir. The most significant BWA damage is in subalpine fir stands at high elevation. In 2022, approximately 30,000 acres with damage were observed, slightly below the 10-year average of 33,400 acres, and similar to levels seen in 2019 **(Fig. 22)**. The majority of BWA damage occurs on federal land.

BWA damage, primarily to subalpine fir and Pacific silver fir, was recorded at high elevations in the eastern Olympic Mountains, and in scattered areas near the crest of the Cascade Mountains from Yakima County north to Whatcom and Okanogan counties. Levels of damage in the Selkirk Mountains appeared to decline in 2022. BWA infestations are often chronic and cumulative effects may result in mortality. There were approximately 4,300 acres with some host mortality attributed to BWA damage in 2022.

Western balsam bark beetle is another important mortality agent in subalpine fir stands that may attack trees weakened by BWA infestation. Approximately 39,400 acres in these same high elevation areas were mapped with some western balsam bark beetle caused mortality in subalpine fir. BWA infestation can be a predisposing factor to western balsam bark beetle attack.

BALSAM WOOLLY ADELGID 10-YEAR TREND FOR TOTAL ACRES AFFECTED IN WASHINGTON Figure 22.



INSECTS | WOOD BORERS

BENJAMIN SMITH

Emerald Ash Borer

(*Agrilus planipennis* Fairmaire)

NON-NATIVE

The June 30, 2022 detection of emerald ash borer (EAB) in the northwest Oregon city of Forest Grove increases the potential of this serious, non-native, forest insect pest moving into Washington. The small, metallic green, wood-boring beetle attacks and kills true ash trees (*Fraxinus* species), the primary host trees for EAB. The larvae burrow under tree bark, eat the phloem, and etch tunnels into the sapwood. Once damaged, these vascular tissues can't transport water and nutrients, causing the leaves and tree to die slowly.

EAB has killed over 100 million ash trees in eastern North America since its original introduction to Michigan in 2002. Since then, it has spread to 36 states and moved gradually westward. An EAB infestation could devastate the ash component of Washington's forests, as well as sensitive riparian areas where the native Oregon ash (*Fraxinus latifolia*) is a keystone species. Infestations of ornamental ash in urban forests will result in very costly removal and replacement activities.

Efforts to eradicate EAB by state and federal agencies in infested areas across the United States and Canada have been unsuccessful. In order to help slow the spread of EAB, a quarantine in Oregon's Washington County is in place to reduce potential movement of infested wood and nursery stock to unaffected areas. More information about the situation in Oregon can be found at the Oregon Department of Agriculture website: https://www.oregon.gov/oda/programs/IPPM/SurveyTreatment/Pages/EmeraldAshBorer.aspx.

Diligence by the public to avoid moving firewood and other potentially infested ash materials are more important than ever.

The most common symptoms of infestation in true ash trees are crown and branch dieback, and unusual leaf sprouting from trunks (Fig. 23). More direct signs of EAB activity include distinctive serpentine galleries under the bark of dead trees and small (about one-eighth inch), D-shaped exit holes through the bark (Figs. 24 & 25). Adults are about one-third to one half-inch in size, with a slim, pointed body shape and a dull, metallic green color.

DARIA GOSZTYLA / DNR

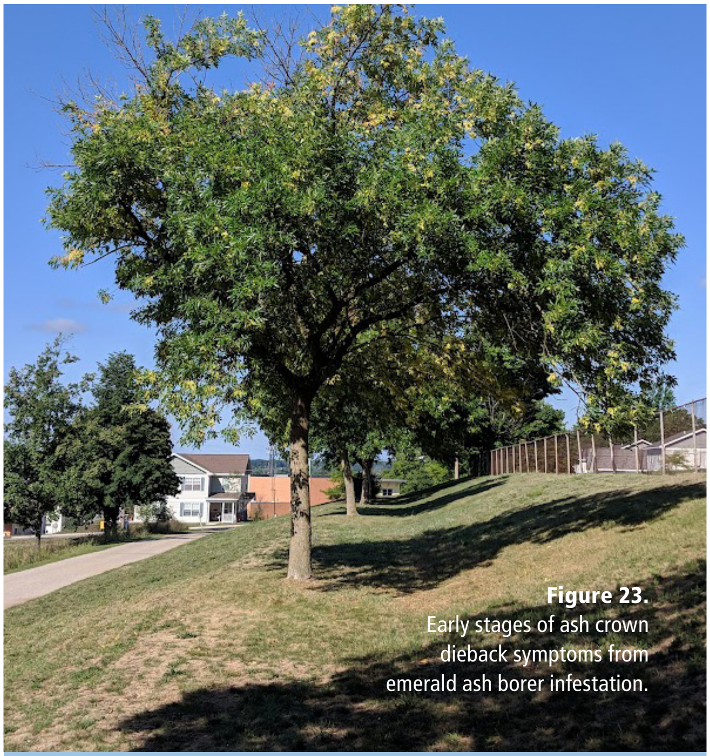


Figure 23. Early stages of ash crown dieback symptoms from emerald ash borer infestation.

EMERALD ASH BORER HAS KILLED OVER 100 MILLION ASH TREES IN EASTERN NORTH AMERICA SINCE ITS ORIGINAL INTRODUCTION TO MICHIGAN IN 2002.

Adult beetles are needed for positive identification, but are rarely seen in areas with new introductions and outside their May to July flight period. Traps used for EAB monitoring are only partially effective at detecting new infestations.

The public is encouraged to report suspected EAB sightings or damage to ash trees. In Washington State, report a sighting at https://invasivespecies.wa.gov/priorityspecies/emerald-ash-borer/.

In forested areas, there are several native species of metallic green wood borer adults in the same family as EAB (Buprestidae). These are commonly referred to as "jewel beetles" and look very similar to EAB. In addition, there are a number of unrelated insect species with metallic green coloration. A guide to potential look-alikes can be found at the Oregon Department of Agriculture website on page 38.

AN EMERALD ASH BORER INFESTATION COULD DEVASTATE THE ASH COMPONENT OF WASHINGTON'S FORESTS, AS WELL AS SENSITIVE RIPARIAN AREAS WHERE THE NATIVE OREGON ASH (*FRAXINUS LATIFOLIA*) IS A KEYSTONE SPECIES.

EAB is a serious and destructive threat to urban and community forests where ash has been planted. Washington communities can prepare by identifying and inventorying ash in cities, learning how to recognize and report potential EAB infestations, increasing species diversity, avoiding ash in tree planting projects, and by destroying or preventing movement of dead ash wood material. In partnership with the Washington Invasive Species Council and other collaborators, the DNR Urban and Community Forestry program developed the Urban Forest Pest Readiness Playbook to help communities prepare for invasive pest outbreaks. You can read more about the ongoing project here and learn about actions that your town and community can take to prepare for a pest outbreak: https://invasivespecies.wa.gov/projects/pest-ready/.

DARIA GOSZTYLA / DNR

Figure 24.
D shaped exit hole made by newly emerged emerald ash borer adult.

DARIA GOSZTYLA / DNR

Figure 25.
Emerald ash borer larval galleries under ash bark.

DISEASES | ROOT ROTS

Variety of Fungi or Water Molds

MOSTLY NATIVE

A variety of root rot diseases impact forests throughout Washington. These include Armillaria root rot (*Armillaria solidipes*, also known as North American *A. ostoyae*, **Fig. 26**); Heterobasidion root rot (*Heterobasidion irregulare* or *H. occidentale*, formerly *H. annosum* P-type and S-type, respectively, **Fig. 27**); and laminated root rot (*Coniferiporia sulphurascens, Phellinus sulphurascens*, **Fig. 28**).

Root rot diseases in Washington forests are caused by native fungi and are a well-established part of our forest system (the exception being the non-native water mold *Phytophthora lateralis*, which causes Port-Orford-cedar root disease in non-native Port-Orford-cedars). Root rot diseases are persistent in our forests, where they affect tree growth and cause tree mortality **(Fig. 29)**. Root rot diseases are very challenging to manage and are typically considered "diseases of the site." Correct identification of the specific fungus is important for determining management response.

Root rots are difficult to monitor during the aerial detection survey (ADS), as their signature is not clearly seen from above and, if mapped at all, are often classified under an associated disturbance category (for example, see 'bear damage' and 'Douglas-fir beetle'). Despite our inability to map these pathogens from the air, root rot diseases are a common management concern in Washington forests and represent a large portion of site visits and questions DNR's forest pathologists respond to.

RACHEL BROOKS / DNR

Figure 26 (top): Armillaria root rot white mycelial fans under removed bark (middle) and developing mushrooms (lower).

Figure 27 (left): Heterobasidion root rot fruiting bodies (conks) in decayed stump.

Figure 28 (bottom): Laminated root rot advanced decay.

RACHEL BROOKS / DNR

Figure 29.
Typical canopy gap caused by root rot pathogens.

ROOT ROT DISEASES ARE VERY CHALLENGING TO MANAGE AND ARE TYPICALLY CONSIDERED "DISEASES OF THE SITE."

DISEASES | CANKERS

USFS

White Pine Blister Rust

(Cronartium ribicola)

NON-NATIVE

RACHEL BROOKS / DNR

The non-native fungal pathogen *Cronartium ribicola*, the cause of white pine blister rust (WPBR), was accidently introduced into North America more than 100 years ago. All nine native U.S. species of white pine (five-needle pines) are highly susceptible to the disease, with mortality rates greater than 90% on high-hazard sites. Today, this pathogen is found throughout Washington, where it has caused widespread mortality in both western white pine (*Pinus monticola*) and whitebark pine (*Pinus albicaulis*).

In December 2022, the U.S. Fish and Wildlife Service listed whitebark pine as a threatened species under the Endangered Species Act. This high-elevation tree is considered a keystone species in high alpine ecosystems in North America where it helps slow snowmelt, reduce erosion, and provide a high-energy food source to wildlife. The tree's decline is driven by WPBR and compounded by bark beetle outbreaks, wildfires, and climate change.

DNR, in collaboration with USFS, local tribes, and British Columbia, maintains four long-term research field sites focused on better understanding the natural genetic variation found within whitebark pine and its susceptibility to WPBR (See FHH 2020 & FHH 2021). Assessments and maintenance of these sites, as well as 12 others focused on western white pine, are ongoing.

RACHEL BROOKS / DNR

RACHEL BROOKS / DNR

Top: A surviving whitebark pine in Okanogan County with a stand of fire killed trees in the background.

Left: A whitebark pine killed by WPBR in Okanogan County.

Bottom: A WPBR canker on a whitebark pine actively producing spores.

DISEASES | CANKERS


JOSEPH OBRIEN / USDA FOREST SERVICE, BUGWOOD.ORG

Sudden Oak Death

(*Phytophthora ramorum* Werres et al.)

NON-NATIVE

Phytophthora ramorum **(Pr) is the causal agent of Sudden Oak Death, ramorum leaf blight, and ramorum dieback. Invasive in North America, *Phytophthora ramorum* has caused extensive mortality of tanoaks and several oak species in southwestern Oregon and California. Luckily, Oregon white oak (*Quercus garryana*) is not considered susceptible. This pathogen can move through landscapes via wind and wind-driven rain, and can be moved long distances by humans on nursery plant material. Due to the presence of other susceptible hosts (including rhododendrons and larch), suitable climatic conditions, and plant nurseries with Pr-infected stock, Washington remains at risk for Pr spread and Pr-caused disease. However, to date, damage similar to that caused by Pr in forests of Oregon and California has not been observed in Washington.**

With funding provided by the USFS National *Phytophthora ramorum* Early Detection Survey of Forests, six western Washington waterways (two in Grays Harbor County and one each in in Clark, Cowlitz, Lewis, and Mason counties) and six eastern Washington waterways (two in Okanogan County and one each in Ferry, Pend Oreille, Spokane, and Stevens counties) were surveyed for Pr in 2022 using a rhododendron leaf baiting method **(Figs. 30 & 31)**. Selected western Washington sites were downstream of known positive or trace forward Pr locations identified by WSDA (either nursery or residential locations). Selected eastern sites were located in watershed that contain large numbers of western larch (*Larix occidentalis*), a susceptible host for Pr. Sites were sampled six times from March through June.

No sampling location in Washington tested positive for Pr in 2022. Overall, most sampled waterways in Washington are free from Pr, with the exception of the Sammamish River, which has regularly tested positive for Pr since 2007 **(Table 2; Fig. 31)**. There has been no indication to date that the pathogen is leaving the waterways, as all vegetation samples collected in the woodlands bordering these waterways have been negative for Pr.

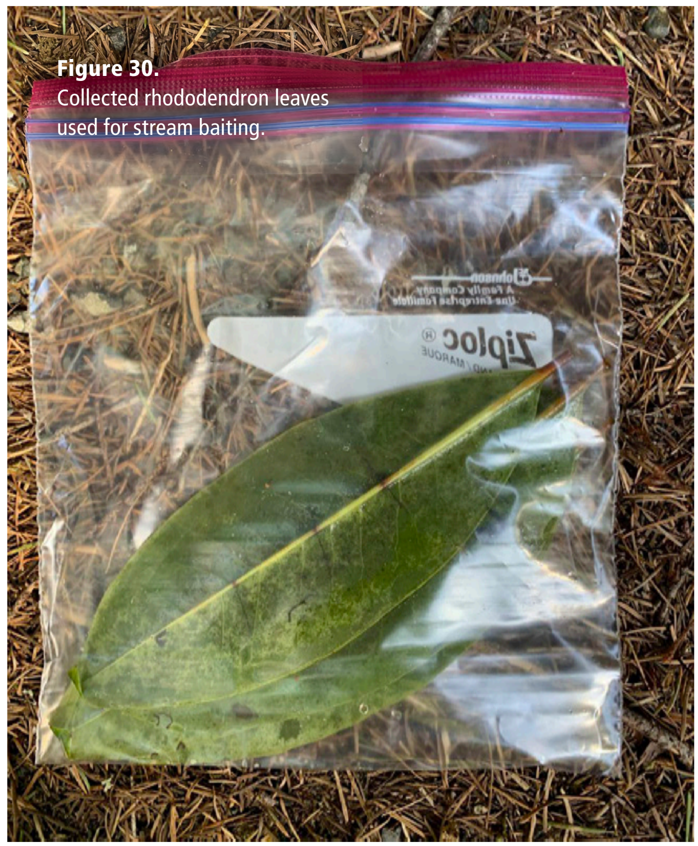

RACHEL BROOKS / DNR

Figure 30. Collected rhododendron leaves used for stream baiting.

INVASIVE IN NORTH AMERICA, *PHYTOPHTHORA RAMORUM* HAS CAUSED EXTENSIVE MORTALITY OF TANOAKS AND SEVERAL OAK SPECIES IN SOUTHWESTERN OREGON AND CALIFORNIA.

DISEASES | CANKERS

Table 2. Monitoring history of waterways that have tested positive for *Phytophthora ramorum* (Pr).

Years with positive detections are indicated with a red square and a plus sign. Years with no detection are indicated with a blue square and a minus sign. White squares indicate years the waterway was not surveyed. Only positive waterways are included in this table.

COUNTY	WATERWAY	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Clallam	Dungeness River & Canals									+	+	–	–						
King	Bear Creek							+	–										
King	Cottage Lake Creek								+	–									
King	Issaquah Creek										–	–	–	+					
King	Little Bear Creek							+	–								+		
King	Mill Creek																	+	
King	Sammamish River			+	+	+	+	+	+	+	+	+	+	+	+	+			
King	Woodin Creek						+	+	+										
Kitsap	Issel Creek										+	+							
Lewis	Mill Creek							+	+			–	–						
Pierce	Unnamed stream, Rosedale		+	–	+														
Snohomish	Evans Creek																+		
Thurston	Woodard Creek								–	+	–	+							
TOTAL POSITIVE WATERWAYS		0	1	1	2	1	2	5	4	3	3	3	1	2	1	1	2	1	0

+ Year with positive detection   – Year with no detection   ☐ Year not surveyed

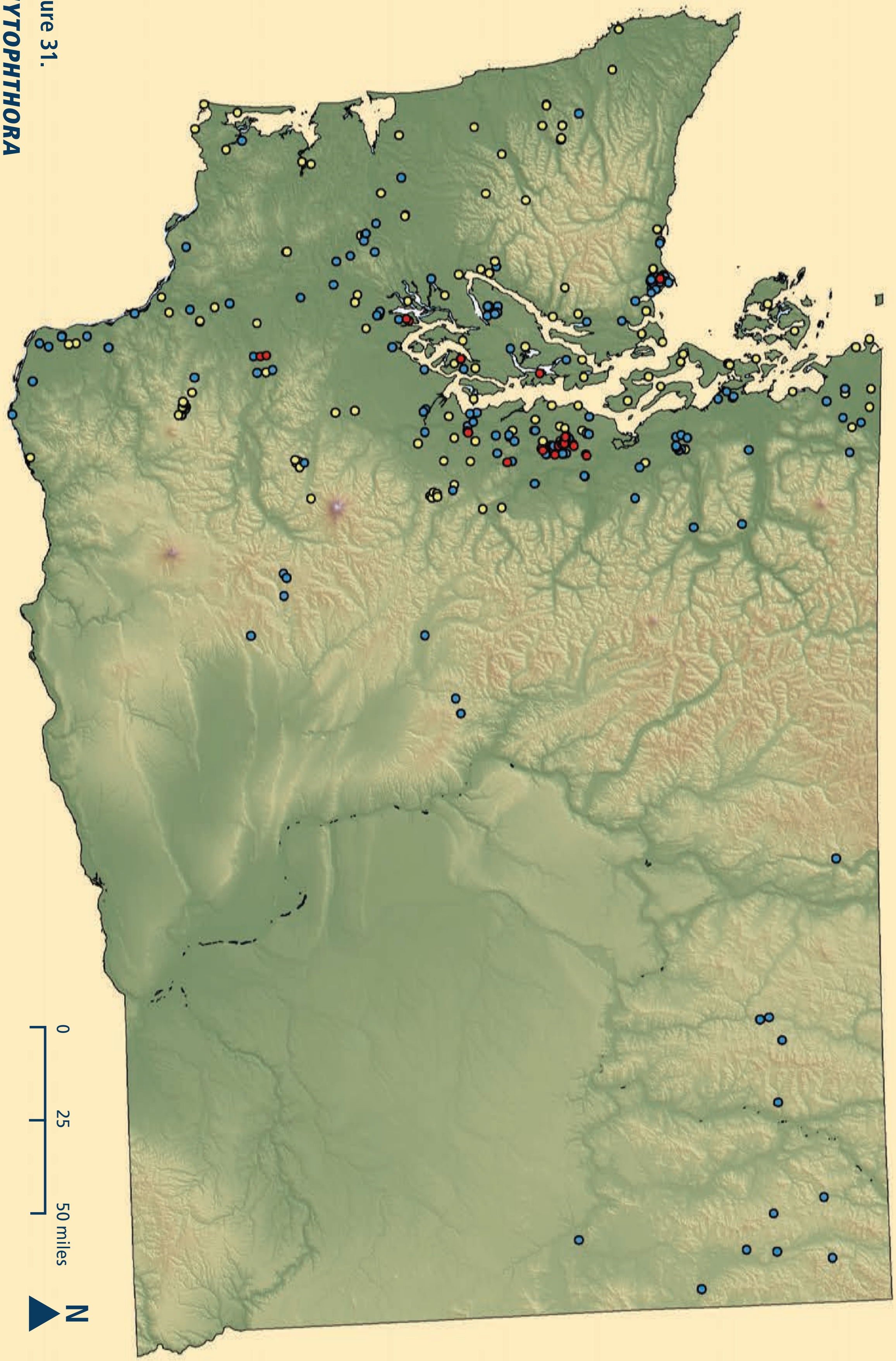


Figure 31. ***PHYTOPHTHORA RAMORUM* SAMPLING LOCATIONS 2003-2022**

DNR *Phytophthora ramorum* monitoring, detection, and survey sites, 2003-2022.

DISEASES | CANKERS

RACHEL BROOKS / DNR

Sooty Bark Disease of Maple

(Cryptostroma corticale)

POSSIBLY NON-NATIVE

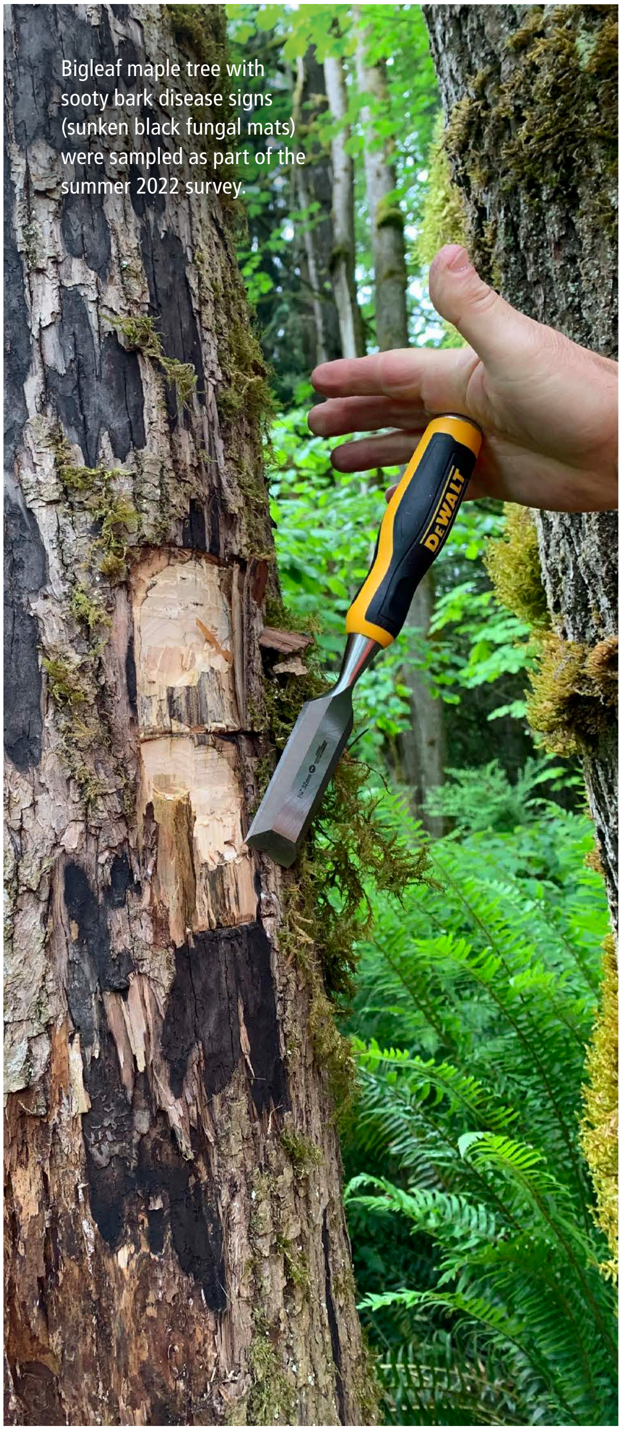
The fungus *Cryptostroma corticale* is thought to be native to the Great Lakes Region of the U.S., where it is considered a saprophyte (only surviving on dead material and not impacting living plants). However in Europe, where it was accidentally introduced sometime before 1945, it causes sooty bark disease (SBD) on several species of maple. On Europe's native sycamore maple (*Acer pseudoplatanus*), SBD often causes wilted leaves, branch dieback, cankers (killed cambium/sapwood), stained wood, and tree death. Disease levels in Europe have been shown to increase after hot and dry summers, especially in urban areas. To help identify possible diseased trees, a "Sooty Bark Disease Diagnostic Guide" is now available online at https://pubs.extension.wsu.edu/sooty-bark-disease-diagnostic-guide.

In Washington, reports of *C. corticale* were rare until recently, when Seattle Parks and Recreation and Washington State University (Puyallup, WA) began confirming numerous positive samples from around the Seattle area. Samples have now been confirmed north to Bellingham, south into Oregon, and as far east as Pullman. These samples have confirmed the presence of *C. corticale* mainly on maple trees (*Acer* spp.), including on bigleaf maple (*Acer macrophyllum*), our only native canopy maple.

To help determine the distribution of this pathogen on bigleaf maple, DNR (in collaboration with the USFS Forest Health Protection, WSDA Plant Pathology and Molecular Diagnostic Lab, WSU Molecular Bioseceine Lab, and Washington State Parks) surveyed 50 western Washington State Parks properties during the summer of 2022. Of these, 46 properties had bigleaf maple present to examine. In total, 39 properties had at least one bigleaf maple with typical SBD signs in which *C. corticale* presence was confirmed on a collected bark sample. Additionally, sampled cores from healthy mature (DBH>12") bigleaf maples tested positive for *C. corticale* at 42 of the properties **(Fig. 32).**

This survey indicates that SBD signs on bigleaf maple are likely well distributed throughout western Washington, though they were still rare on individual bigleaf maple trees inspected. The core samples, detecting mature bigeleaf maples with latent infections (infected but with no disease expression), appear well distributed and common throughout western Washington. Despite *C. corticale*'s wide distribution, bigleaf maples were prevalent and vigorous at most properties. This study has been submitted for peer-review publication and will be available upon request when published.

Additional research is still needed to confirm *C. corticale*'s pathogenicity, consider its nativity, and determine the long-term consequences it may have on our street and forest trees.



Bigleaf maple tree with sooty bark disease signs (sunken black fungal mats) were sampled as part of the summer 2022 survey.

RACHEL BROOKS / DNR

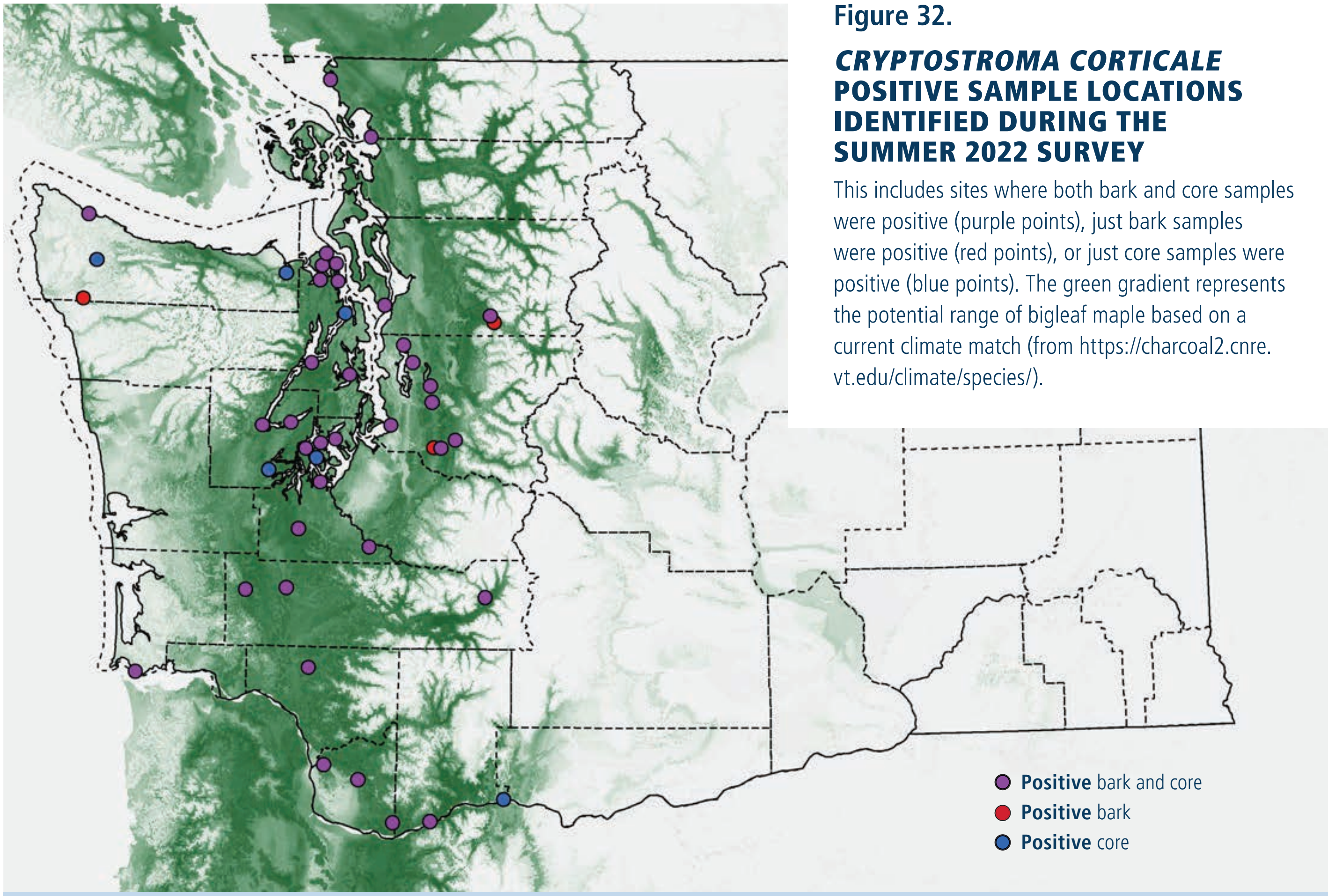


Figure 32.

CRYPTOSTROMA CORTICALE POSITIVE SAMPLE LOCATIONS IDENTIFIED DURING THE SUMMER 2022 SURVEY

This includes sites where both bark and core samples were positive (purple points), just bark samples were positive (red points), or just core samples were positive (blue points). The green gradient represents the potential range of bigleaf maple based on a current climate match (from https://charcoal2.cnre.vt.edu/climate/species/).

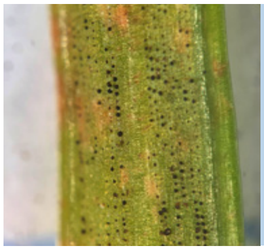
RACHEL BROOKS / DNR

A healthy and mature bigleaf maple tree cored as part of the summer 2022 survey.

THIS SURVEY INDICATES THAT SOOTY BARK DISEASE SIGNS ON BIGLEAF MAPLE ARE LIKELY WELL DISTRIBUTED THROUGHOUT WESTERN WASHINGTON, THOUGH THEY WERE RARE ON INDIVIDUAL BIGLEAF MAPLE TREES INSPECTED.

DISEASES | FOLIAR DISEASES

RACHEL BROOKS / DNR



Swiss Needle Cast

(*Nothophaeocryptopus gaeumanni*)

NATIVE

***Nothophaeocryptopus gaeumannii*, the fungus that causes Swiss needle cast (SNC), is found wherever Douglas-fir (*Pseudotsuga menziessii*) – its only host – is planted. This native foliar disease rarely causes tree mortality, but can cause needle discoloration and premature foliage loss that may result in reduced tree growth. This pathogen became a priority in the coastal forests of Washington and Oregon in the late 1980s and early 1990s, and has more recently become a concern in British Columbia. These areas have likely seen impact due to the fungi-favorable topographic and climatic conditions (such as mild winters and wet springs), historical plantings using off-site seed sources, and increases in Douglas fir numbers due to forest management practices. Ground and aerial surveys monitoring this disease and its symptoms have been conducted in Washington for many years.**

In May 2022, an aerial survey covering 2.0 million acres of land along the coast mapped the distribution of discolored Douglas-fir trees typically associated with SNC (Fig. 33). The observation aircraft flew 1,500 to 2,000 feet above ground level on a 3-mile grid, with observers on both sides of the aircraft identifying areas of Douglas-fir forest with yellow-brown foliage (Fig. 34). Just over 115,000 acres of Douglas-fir displaying symptoms were mapped, representing about 6% of the total area surveyed (Table 3). Severely symptomatic stands were generally located between Westport and Ilwaco, while moderately symptomatic stands were found scattered throughout the region (Fig. 33). The total acreage mapped is within the range of previous measurements (a slight increase from the previous survey conducted in 2018, but a decrease from earlier surveys, Table 3). Note that aerial surveys detect discoloration in trees, not necessarily SNC severity or impacts.

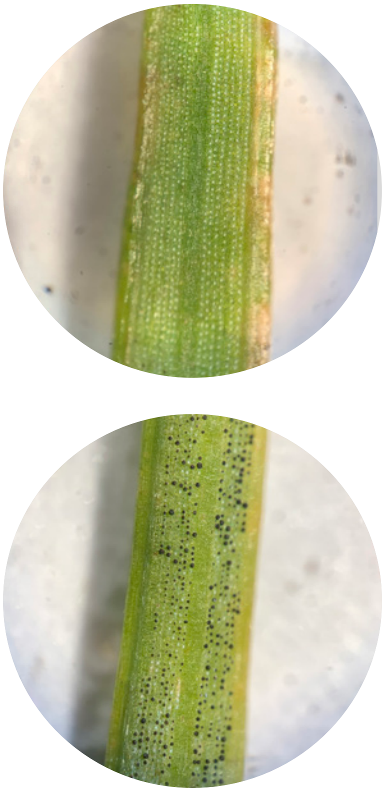


Figure 35.
The underside of two-year old needles collected during SNC ground plot monitoring showing an uninfected needle (top) and an infected needle with about a 70% SNC severity rating (bottom). Unobstructed stomata are seen as white dots in vertical rows while SNC fruiting body occluded stomata are seen as black dots.

To support the aerial survey, observers assessed 96 ground locations across the same coastal range of the aerial survey in 2021 and 2022. SNC severity, represented by the percentage of stomata blocked by fungal fruiting bodies on two-year-old needles, (Fig. 35), and needle retention (the number of years on a branch retaining needles) was estimated at an appropriate and accessible stand no farther than four miles from each location. An average of 2.5 (2021) and 2.1 (2022) needle retention years and 21.1 (2021) and 8.9 (2022) percent SNC severity were measured at these coastal plots. These measurements were similar or lower than measured in previous surveys (Table 4).

Additionally, during the same period, 32 ground plots were surveyed in the Northwest Region (Whatcom and Skagit counties) in an area previously not monitored. An average of 2.9 (2022) and 2.4 (2021) needle retention years and 35.9 (2021) and 25.6 (2022) percent SNC severity were measured. These numbers are significantly higher than those measured along the coast during the same time period (Table 4; Fig. 36).

These ground surveys found that SNC severity and needle retention varied between site, regions, and by year. Correlation between needle retention and disease severity were assessed for each region each year. The correlation between SNC severity and needle retention was not

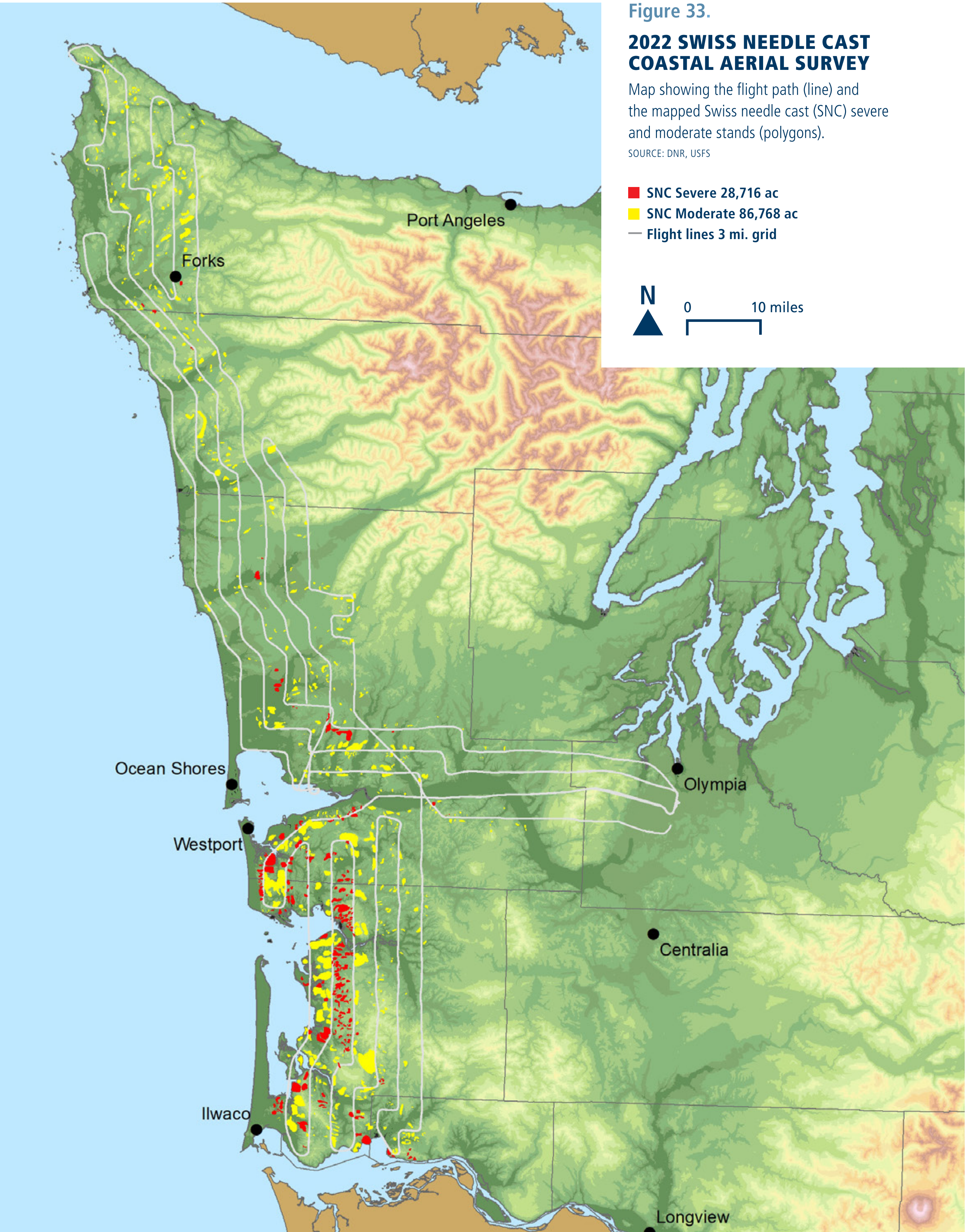


Figure 33.

2022 SWISS NEEDLE CAST COASTAL AERIAL SURVEY

Map showing the flight path (line) and the mapped Swiss needle cast (SNC) severe and moderate stands (polygons).

SOURCE: DNR, USFS

- SNC Severe 28,716 ac
- SNC Moderate 86,768 ac
- Flight lines 3 mi. grid

N

0 10 miles

YEAR	SEVERE SNC SYMPTOMS		MODERATE SNC SYMPTOMS		TOTAL SNC SYMPTOMS		AREA FLOWN
	% OF TOTAL ACRES	SEVERE SNC ACRES	% OF TOTAL ACRES	MODERATE SNC ACRES	% OF TOTAL ACRES	TOTAL SNC ACRES	ACRES IN MILLIONS
2022	1%	29,000	4%	87,000	6%	115,000	2.0
2018	< 1%	6,000	3%	73,000	3%	79,000	2.7
2016	< 1%	14,000	10%	234,000	10%	248,000	2.4
2015	1%	19,000	13%	332,000	14%	351,000	2.6
2012	< 1%	6,000	8%	222,000	9%	228,000	2.7

REGION	YEARS	NUMBER OF SITES	AVERAGE SNC SEVERITY (%)	AVERAGE NEEDLE RETENTION
Coastal	2022	48	8.9	2.1
	2021	48	21.1	2.5
	2018	26	16.0	2.3
	2016	63	22.1	2.4
	2015	47	22.5	2.3
	2012	75	15.5	2.2
NW	2022	17	25.6	2.4
	2021	15	35.9	2.9

Table 3 (above). 2022 aerial survey results compared to previous years of SNC aerial survey results in the coastal region of Washington.

Table 4 (left). Sampled region, year sampled, number of sites sampled, average percentage of occluded stomata on two-year-old needles (SNC severity), and average needle retention (0 indicates there were no needles retained and 3.6 indicates full retention of 4-years of foliate) for each region surveyed since 2012.

significant in all locations and years except for the Northwest Region in 2022, which was the only region to display the expected correlation between high SNC severity and low needle retention. This overall lack of correlation is of note, as it may indicate other stressors such as drought, heat, site quality, or other foliar diseases are driving needle retention, in addition to SNC.

Both the coastal ground survey and aerial survey indicate there has been no substantial increase in the severity of SNC over the past decade in coastal Washington, as acreage mapped during the aerial survey and SNC ratings from the ground survey are within or below the measurements observed in previous surveys. Results from the Northwest Region are inconclusive, as no previous measurements exist for that region, and because their measurements indicate better levels of needle retention than the coastal region despite having higher SNC severity measurements.

These regional surveys are used to coarsely document trends over time. Therefore, site-specific ground surveys should be conducted in stands of interest before specific SNC mitigating management decisions are made. For a more detailed management discussion, refer to the "Silvicultural decision guide for Swiss needle cast in coastal Oregon and Washington" available online at: extension.oregonstate.edu/pub/em-9352.

This survey was conducted in collaboration with the USDA Forest Service, the Washington State Department of Fish and Wildlife, and the University of Washington. The Washington State Legislature funded it. Additional survey details can be found in DNR's full report, available online at https://sncc.forestry.oregonstate.edu/annual-reports in the 2022 annual report.

RACHEL BROOKS / DNR

Figure 34. Discolored yellow-brown Douglas-fir (left) and normal-colored dark-green Douglas-fir stand (right). Lighter trees scattered throughout are hardwoods.

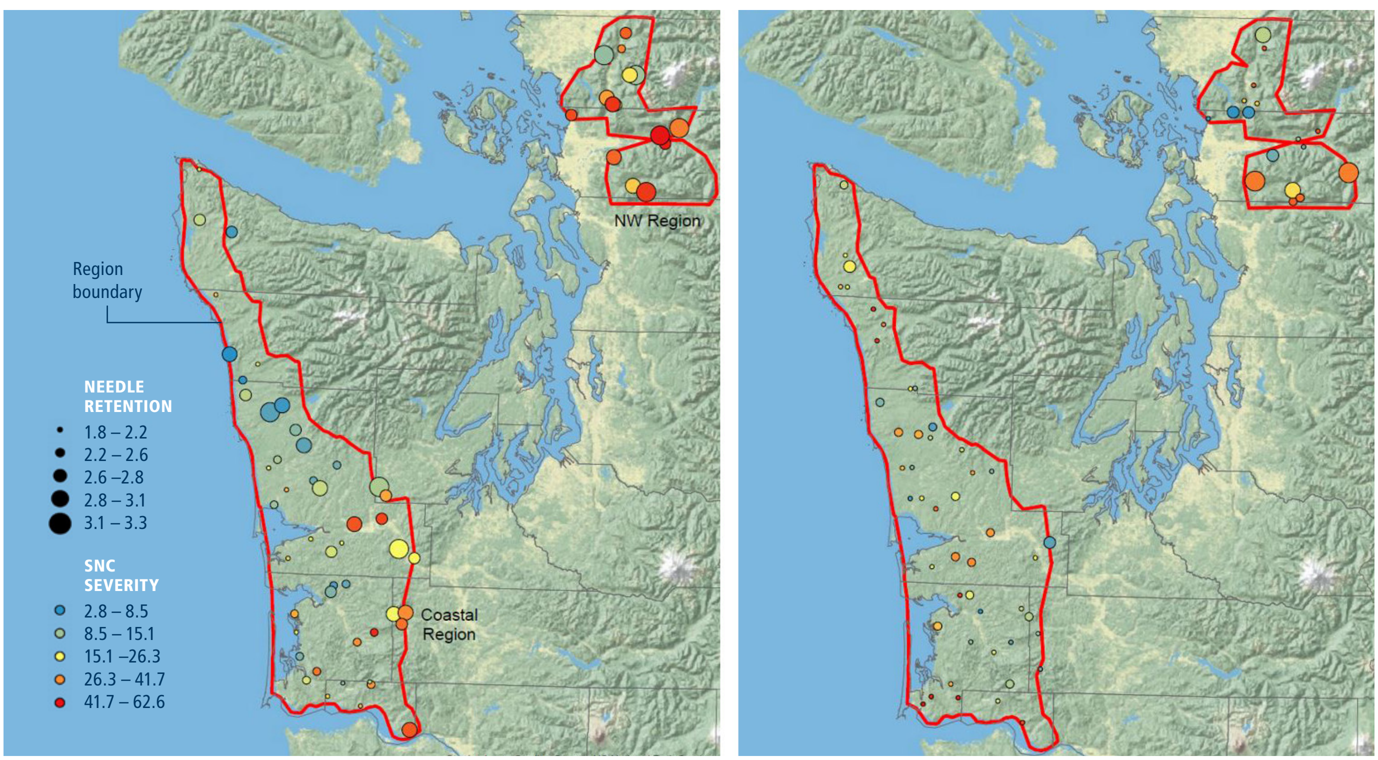


Figure 36.

SWISS NEEDLE CAST (SNC) GROUND SAMPLING RESULTS

SNC ground survey plot results in 2021 (left) and 2022 (right). Regions of interest are outlined in red with points representing sampled plots locations. Point size indicates average needle retention and point color represents disease severity. SOURCE: DNR, USFS

DISEASES | FOLIAR DISEASES

NEEDLE CAST AND NEEDLE BLIGHT: USDA; LARCH CASEBEARER: CONNECTICUT AGRICULTURAL EXPERIMENT STATION

Larch Needle Cast

(*Rhabdocline laricis*)

NATIVE

Larch Needle Blight

(*Hypodermella laricis*)

NATIVE

Larch Casebearer

(*Coleophora laricella*)

NON-NATIVE

RACHEL BROOKS / DNR

Figure 37. Larch needle cast discoloration in lower crown.

A variety of fungi and insects impact larch foliage. Observers mapped larch defoliation on approximately 27,500 acres in 2022, a severe increase from the 3,300 acres mapped in 2021, but not quite as high as when larch casebearer affected 39,000 acres in 2008. Of these acres affected, defoliation due to larch needle cast (*Rabdocline laricis*) was mapped on approximately 27,300 acres, driving the increase. Foliage discoloration in the lower crown **(Fig. 37)** is the distinctive damage signature of larch needle cast as viewed from the aircraft. Discolored whole crowns of western larch, indicative of both larch needle blight (*Hypodermella laricis*; **Fig. 38**) and larch casebearer (*Coleophora laricella*) were observed on approximately 100 acres. Larch needle cast and larch needle blight can be found on the same tree, though the two are mapped separately based on the dominant signature as seen from the air. This increase in acres affected was likely driven by a cool, wet spring, which favors fungal infection and development on foliage. Despite this increase in acreage and striking symptoms, long-term impacts on forest stands from these foliar diseases are minimal.

RACHEL BROOKS / DNR

Figure 38. Larch needle blight killed needles with black fruiting bodies visible.

DISEASES | FOLIAR DISEASES

CROTHFELS

Powdery Mildew

Likely *Sawadaea bicornis*

NON-NATIVE

BOTTOM PHOTOS: RACHEL BROOKS / DNR

Figure 39. White tinted foliage on bigleaf maple seen in the bottom half of this photo during an ADS survey in Whatcom County. Though visible in this photograph, powdery mildew signature was rarely observed from above, and therefore not mapped during the ADS survey.

Figure 40. Powdery mildew s white fungal growth on bigleaf maple foliage in Whatcom County.

An outbreak of powdery mildew (likely caused by the non-native fungus *Sawadaea bicornis*) was observed on bigleaf maple (*Acer macrophyllum*) throughout western Washington in spring 2022. When infected, white fungal material grows on leaf surfaces, causing discoloration **(Figs. 39 & 40)**. Similar to most foliar diseases, this powdery mildew will likely have minimal impact on healthy trees, and will be inconspicuous once new leaves appear in spring.

Western Redcedar Dieback Monitoring

In 2022, approximately 105,000 acres with western redcedar (WRC) dieback and mortality were observed throughout Washington, a significant increase from the 46,000 acres mapped in 2021. The affected area has increased every year since aerial mapping of WRC dieback began in 2017. Symptoms of dieback include thinning crowns, discoloration (yellowing or browning) of the needles, heavy cone crops, branch dieback and flagging, topkill and mortality (Fig. 41). The highest concentrations of damage in western Washington were in the Olympic National Forest, Olympic National Park, San Juan Islands, Whidbey Island, and throughout Whatcom, Skagit, Snohomish, King, Kitsap, and Clark counties. In northeast Washington, Pend Oreille County and northern Ferry and Stevens counties were most affected.

Crews observed damage agents at some sites, including cedar bark beetles (*Phloeosinus* species), wood-boring beetles, and root diseases, but these are typically secondary damage agents taking advantage of host trees stressed by another inciting factor. Given the wide range of damage, an abiotic issue, such as drought stress and/or higher than normal temperatures, is likely causing the dieback.

To determine the extent of WRC dieback and variables associated with the dieback, the Oregon Department of Forestry, DNR, and the U.S. Forest Service started a cooperative monitoring project in 2021. Observers geo-referenced 200 sites across Washington with WRC dieback. Detailed

BETSY GOODRICH / USFS

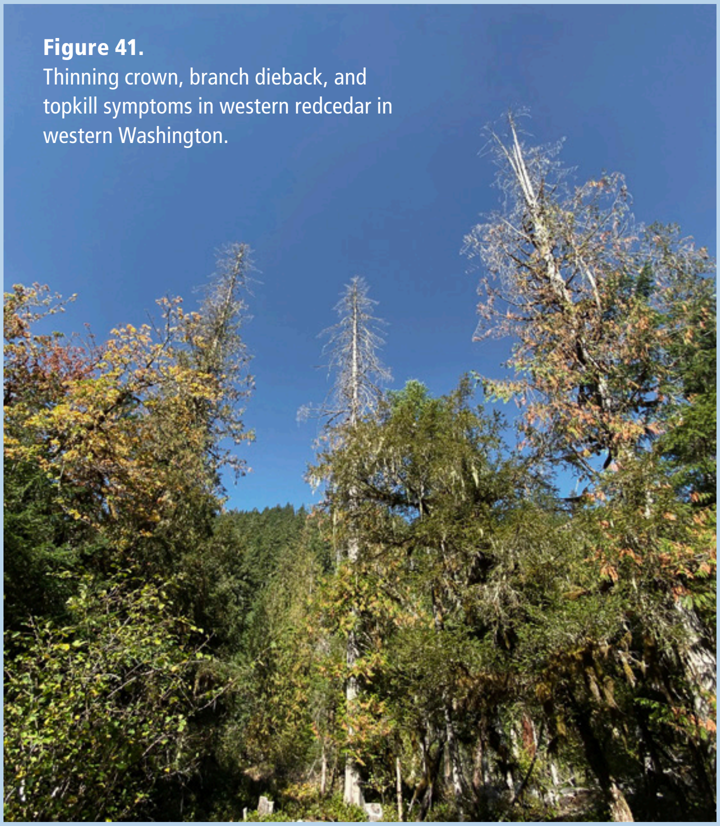


Figure 41.
Thinning crown, branch dieback, and topkill symptoms in western redcedar in western Washington.

site and stand information were collected at 80 sites. A subset of permanent plots for long term monitoring of WRC dieback are being followed for several years in Oregon and Washington. A story map with more information about this project can be found at https://storymaps.arcgis.com/stories/1405dab5f59246aa83849ec43f72b15a.

Throughout the Pacific Northwest, field observations of WRC condition made by the public can be viewed and reported as part of the Western Redcedar Dieback Map community science project hosted on iNaturalist: https://www.inaturalist.org/projects/western-redcedar-dieback-map.

ANIMALS | BEAR DAMAGE / ROOT DISEASE

Aerial surveys record scattered, pole-sized, newly dead trees of all conifer species as "bear damage." Based on ground checks and observations of aerial survey polygons, bear girdling and root disease are the primary causes of this distinct damage pattern. Drought, secondary bark beetles, or cambium-feeding animals, such as porcupines and mountain beavers, may also play roles. This damage signature is most commonly identified in young timber stands in western Washington, but is present throughout all forest types (**Fig. 42**).

When bears emerge from hibernation in spring, they strip bark from trees and feed on the sugary wood beneath. Trees are either girdled entirely, or they become weakened and vulnerable to secondary damage agents. While this behavior is quite common, our ability to detect and record the resulting mortality is variable. It often takes more than a year for the tree to die, its needles to turn red, and the damage to become recognizable from the air. Alternatively, in drought years, trees may fade the same year they are injured. In years with wet and cool spring conditions, the berries that bears feed on mature later, so bears are more likely to exploit more trees as an alternative source of food. Above average spring precipitation may also delay the reddening of bear damaged trees, which may result in less observed damage that year. Other factors that may influence fluctuation in bear damage acreage are local bear populations and the age of trees.

DNR PHOTO

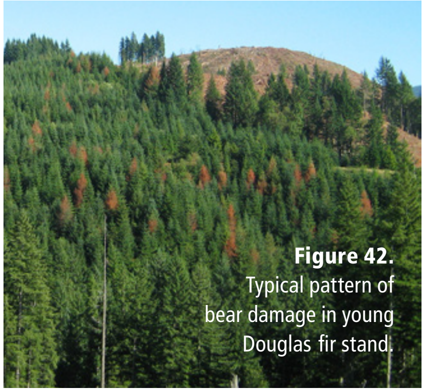
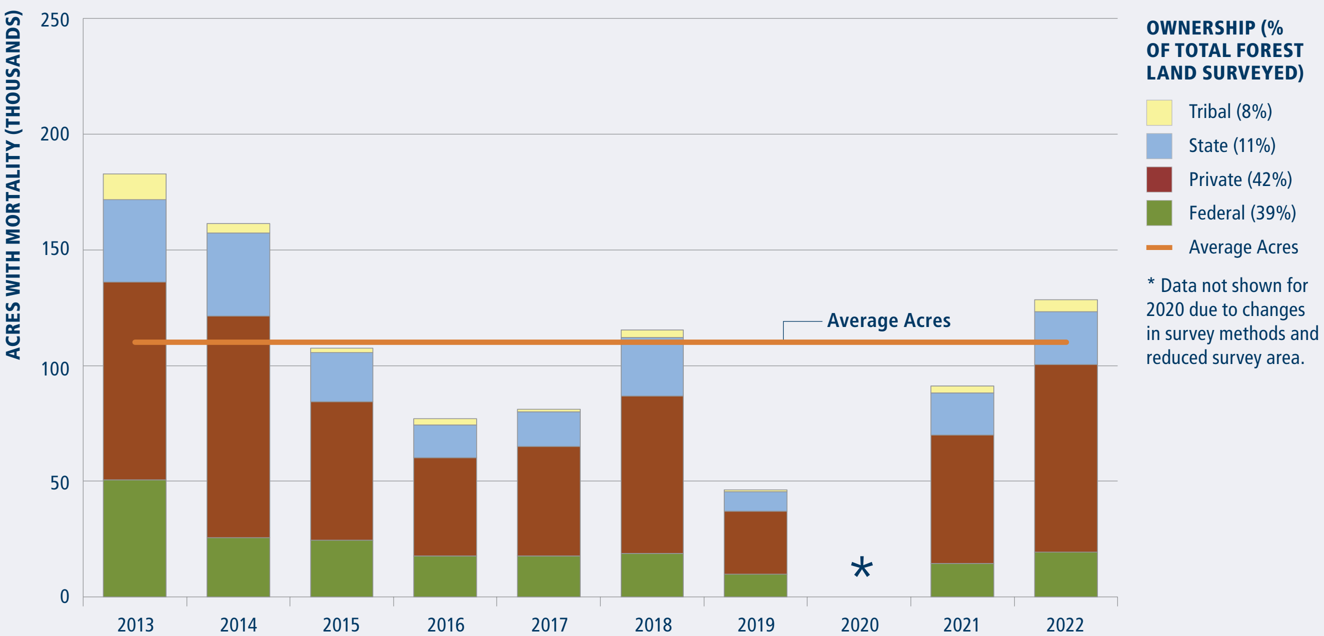


Figure 42. Typical pattern of bear damage in young Douglas fir stand.

Approximately 128,500 acres with bear damage mortality were observed in 2022, a 41% increase from 2021 and above the ten-year average of 110,000 acres (**Fig. 43**). A reduction in areas of western Washington flown in 2021 due to lack of aircraft and crew availability may be one cause of the increase. The total area documented in 2022 is likely a slight underestimate due to areas of western Washington being shrouded in smoke from large, late-season fires. Over the last decade, the total area observed with bear/root disease damage has ranged from a high of 183,000 acres in 2013 to a low of 46,300 acres in 2019.

BEAR / ROOT DISEASE 10-YEAR TREND FOR TOTAL ACRES AFFECTED IN WASHINGTON Figure 43.



Aerial Detection Survey Methodology

Disclaimer: *To accurately identify and record damage observations at a statewide scale is a challenging task that takes many years to master. Even then, mistakes do occur. Sometimes the wrong pest is identified, or the marking on the map is off-target. The aircraft used in aerial survey travel at high speeds, and damage can be overlooked, particularly in areas of diverse, congested damage types. The goal of the program is to correctly identify and accurately map forest damage within ¼ mile of its precise location at least 70% of the time.*

The annual insect and disease aerial detection survey (ADS) to detect recently killed and currently damaged forest trees in Washington is conducted by the USDA Forest Service (USFS) in cooperation with DNR and has been ongoing since 1947. The survey is flown at 90-150 mph between 500 and 1,500 feet above ground level in a fixed-wing airplane. Observers positioned on both sides of the plane look out over a two-mile swath of forestland, recording points or polygons of recently killed or defoliated trees on tablets equipped with specialized digital sketch-mapping software. Aerial observers draw upon training, experience, and pattern recognition to assign each point/polygon with the most likely causal agent and a measure of damage intensity (see section below for more detail). Inferences are made based on the size and species of tree, the appearance of thin or fading foliage, and the pattern of tree mortality or decline. These classifications of characteristics are referred to as “damage signatures” and are discussed in flight continually to ensure observations remain consistent between surveyors.

ADS observers are trained to recognize numerous damage signatures and tree species quickly and confidently. Satellite imagery showing recent management activity as well as spatial and topographic information is displayed on survey tablets, improving accuracy when placing damage polygons. There is always at least one observer in the plane with three or more years of sketch-mapping experience. When interpreting data and maps within this report, do not assume every tree is dead within a given polygon. Damage intensity modifiers define a range of tree mortality or damage, and typically, only a small proportion of trees within a given polygon may actually be recently killed or damaged.

Each year, the perimeters of forestland burned by wildfire are added to aerial survey maps. Dead trees are not recorded within the fire perimeter the following year. The difference between damage caused by wildfire and damage caused by insects or disease is often indistinguishable from the air, so mapping in these areas is avoided. Two years after a fire, when the immediate effects of the burn have mostly subsided, pests can be credited with tree damage and counted in aerial survey totals.

METHODS FOR RECORDING DAMAGE INTENSITY

Damage polygons are assigned a “percent-class” value representing one of five incremental ranges of percent of treed area affected **(Table 5)**. The observer assigns a percent-class value by estimating the canopy area with current year’s damage and visually dividing this by the canopy area of all trees in the polygon. This includes current year damaged, live, and old dead trees as well as non-host trees. For areas affected by defoliating agents, polygons are assigned values for the intensity of within-crown defoliation (L-Light, M-Moderate, H-Heavy). When observers record a point of damage in areas less than 2 acres, they assign a range estimate of the number of trees affected **(Table 6)**.

Table 5. Percent of treed area affected classes used for ADS damage polygons.

PERCENT CLASS CODE	NAME (VALUE RANGE)
1	Very Light (1-3%)
2	Light (4-10%)
3	Moderate (11-29%)
4	Severe (30-50%)
5	Very Severe (>50%)

Table 6. Range classes of individual affected tree counts used for ADS damage points.

POINT CLASS CODE	NUMBER OF TREES AFFECTED (VALUE RANGE)
1	1
2	2 – 5
3	6 – 15
4	16 – 30
5	>30

Adoption of the percent-class/point-range method presents challenges for trend analysis and cumulative mortality assessments when compared to the trees per acre (TPA) data used prior to 2018. Summary statistics of approximate number of trees killed, such as totals and averages by agent, cannot be derived directly from percent-class data. In USFS Region 6 (Oregon and Washington), percent-class polygons are converted to a calculated TPA value using a “histogram matching” method. This method separates several recent years of historical Region 6 TPA data into 5 categories similar in range to the percent-class categories, then calculates a derived TPA value for each percent-class polygon based on the midpoint of each TPA category and the polygon size. Point-range categories are converted to TPA values based on the upper range of each point-class code. All 2022 ADS mortality polygons in DNR’s downloadable GIS datasets use calculated TPA values as intensity modifiers. Region 6 quadrangle reporting maps available as PDFs use percent treed area affected classes or tree ranges as label modifiers (see next page “Data and Services section”).

Data and Services

All 22 million acres of Washington forestland are surveyed by aircraft annually to document recent tree damage and forest health conditions. This aerial survey is made possible by the cooperation of the DNR and the USFS, and is very cost-effective for the amount and quality of data collected. The publically available maps and data produced are convenient tools for monitoring forest disturbance events and forest management planning. They also provide excellent trend information and historical data.

ELECTRONIC PDF MAPS AVAILABLE FOR DOWNLOAD

Traditional insect and disease survey quadrangle maps from 2003 to 2022 are available for download as PDF files at: **www.fs.usda.gov/goto/r6/fhp/ads/maps.**

Select the year of interest under **"Aerial Detection Survey Quad Maps"** to open an interactive map of all the available quads from Oregon and Washington. Decide which quad map you want to view and click the corresponding quad number link in the list below the map to download the PDF. Polygons are colored according to damage type and labelled with a specific damage agent code. The code is followed by a modifier indicating range classes of trees affected, percent treed area affected, or intensity of damage (L-light, M-moderate, H-Heavy). Damage codes are defined in the legend located in the lower left side of each quad map.

INTERACTIVE MAP TOOLS

2015 to 2022 annual aerial survey data and the 15-year cumulative mortality data product are available on Washington DNR's interactive, web-based mapping site: "Fire Prevention & Fuel Management Mapping" at: **https://fmanfire.dnr.wa.gov/**. Navigate to the left hand side of the webpage, click "Forest Health," select "Annual Aerial Survey Data" and the year of interest, then check circles below for the type of damage to be displayed. Agent and intensity are classified by color and shade, respectively. Additional attributes can be viewed by clicking individual polygons. The user can add base maps and background layers. Wildfire data is displayed by default and may be toggled on/off under the "Wildfire & Prevention" tab.

The USFS offers several interactive online services for viewing aerial survey data and learning how it illustrates forest health trends in the Pacific Northwest at: **www.fs.usda.gov/goto/r6/fhp/ads**.

- **Forest Health Summary for the Pacific Northwest Region 2022 story map.** The first link under "What's New" in the main body of the website opens a story map that provides photos of damage agents and their impacts along with a compendium of current forest health conditions.

- **2022 Aerial Survey Data Viewer.** To view 2022 aerial survey data in a web-based map, click the "Learn More" link under "Data Viewer." This web device allows the user to create customized electronic maps with a variety of background layers. For printable maps, zoom in to the area of interest and click on the PDF icon in the upper right. Output PDFs are georeferenced for use in PDF viewer applications on mobile devices.

- **Forest Health Dashboard.** For a breakdown of aerial survey data by a specific region or tree species, click the "Learn More" link under "Forest Health Dashboard." This tool provides the user with an interactive graphic of forest pests and diseases and the acres of damage they were attributed in 2022.

GIS DATA AVAILABLE FOR DOWNLOAD

Washington DNR maintains downloadable GIS datasets, including aerial survey data for Washington State from 1980 to 2022. The feature layer download is titled "Forest Health Aerial Survey 1980-2022" and can be accessed by visiting http://data-wadnr.opendata.arcgis.com/ and clicking the brown "Forest Health" icon beneath the search bar at the top of the page. The USFS maintains a site for combined Oregon and Washington ADS data from 1947 through 2022 (including data from the ground-based 2020 insect and disease survey). Visit **www.fs.usda.gov/goto/r6/fhp/ads** and click "Learn More" under "Data Download."

FOREST HEALTH WEBSITES

Washington Forest Health Highlights reports are published annually and include the latest information on exotic pests, insect and disease outbreaks, and recent forest damage trends throughout Washington. Annual reports and other forest health information are available at **http://www.dnr.wa.gov/ForestHealth**. Click the "Insects and Disease Monitoring" link for more detail on forest health monitoring and reporting.

Historic annual highlights reports for Alaska, California, Oregon, Washington, and Hawaii and the Pacific Islands are available at: **https://www.fs.usda.gov/detail/r6/forest-grasslandhealth/insects-diseases/.**

The USDA Forest Service Forest Health Protection (FHP) program has shared responsibility for monitoring and protecting the health of forest ecosystems in the Pacific Northwest. It provides technical and financial assistance to federal resource managers in Oregon and Washington regarding insects, diseases, and unwanted vegetation in forest ecosystems. Similar assistance is provided through state forestry personnel to state and private resource managers. Learn more at: **https://www.fs.usda.gov/main/r6/forest-grasslandhealth.**

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