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Forest Health Highlights in Washington - 2017

Washington State Department of Natural Resources Forest Health Program

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WILDFIRE

Pacific Northwest Region
Forest Health Protection

Forest Health Highlights in Washington—2017

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Front cover: *Armillaria root disease caused mortality in a 70 year old Douglas-fir forest in western Washington. Photo by Amy Ramsey, Washington DNR.*

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Summary

The 2017 aerial detection survey (ADS) was completed for over 22 million acres of forest lands within Washington, covering a variety of ownerships. In 2017 ADS recorded some level of tree mortality, tree defoliation, or foliar diseases on approximately 512,000 acres. This is an increase from the 407,000 acres with damage in 2016. 2017 was the first year observers mapped in the 1.5 million acres that were affected by wildfires in 2015. The area with *mortality* attributed to bark beetles was approximately 321,000 acres and 82,000 acres with mortality were due to bear damage or root disease. Relative to 2016, tree mortality increased for all major bark beetle species except spruce beetle. The area with conifer *defoliation* was approximately 88,000 acres, primarily caused by western spruce budworm and balsam woolly adelgid. Approximately 30,000 acres had some level of *disease* damage, primarily larch needle blight and needle casts in pines and western larch. It should be noted that disease damage is significantly underrepresented in the ADS data because symptoms are often undetectable from the air. Previous annual totals for all damage agents were:

2016: 407,000 acres **2015:** 338,000 acres **2014:** 543,000 acres **2013:** 593,000 acres

Drought conditions and warm, dry spring weather tend to increase tree stress and insect success, driving acres of damage up in both the current and following year. Wet spring weather tends to increase acres affected by foliage diseases and bear damage in both the current and following year. Precipitation in Washington was below normal during summer 2017, but above normal in spring and fall. Monthly average temperatures were above normal during the summer and near normal in spring and fall. According to the US Drought Monitor, all of Washington was either in moderate drought or abnormally dry condition from mid-August through October in 2017.

Approximately 3.4 million trees were recorded as recently killed in 2017.

The approximately 191,000 acres with **pine bark beetle** activity recorded in 2017 was an increase from the 126,000 acres in 2016. The most significant increases occurred in northern Ferry County, eastern Okanogan County, and Chelan County. **Mountain pine beetle** damage increased to approximately 165,200 acres but is still below the ten-year average of 174,000 acres. Mortality of ponderosa pines due to **western pine beetle** increased to approximately 18,700 acres, the highest level in ten years.

Mortality due to **Douglas-fir beetle** increased relative to 2016, to approximately 48,900 acres, the highest level since 2009. The most significant increases occurred in Asotin, Columbia, Skamania, Klickitat, Kittitas, Chelan, Stevens, and Ferry counties. Increases may be associated with windstorms, drought, and wildfires that occurred in eastern Washington in 2015 in addition to effects of defoliation by the western spruce budworm in the central Cascades.

Fir engraver caused mortality in true firs (*Abies* species) was recorded on approximately 46,300 acres in 2017, the highest level since 2010. Recent drought conditions and effects of past defoliation by western spruce budworm are likely drivers of the increase.

Acres with **western spruce budworm** defoliation in eastern Washington decreased to approximately 40,400 acres, the lowest level since 1983. Most of the activity was in Stevens and Pend Oreille counties. The outbreak in central Washington has collapsed.

Defoliation due to conifer **needle cast diseases** was recorded on approximately 5,100 acres, of which 3,300 acres were on western larch and 1,800 acres were on ponderosa pine and lodgepole pine.

Larch needle blight (*Hypodermella laricis*) damage in western larch was observed on approximately 18,000 acres, primarily in northeast WA.

2017 Weather and Drought Conditions

PRECIPITATION

Total annual precipitation averaged across all climate divisions for Washington was 48.74" in 2017. This is a departure of 6.71" from the 20th century average of 42.03", making 2017 one of the more wet years on record.

For nearly all climate regions across the state, January to March was above average for recorded precipitation (Table 1). In the Northeast counties, Palouse and Blue Mountains, precipitation was greater than 4" above normal, marking the wettest January to March period on record for these locations. April to June was another above average precipitation period for most regions with departure values of nearly 0.5" in the Columbia Basin, 1" – 2" in the Puget Sound, eastern slopes of the Cascades, Okanogan Highlands and the Northeast. Departures in excess of 2" were recorded primarily for west slopes locations of the Cascades and Olympics. During the summer, a series of strong high pressure systems resulted in minimal precipitation for much of the state, including a record-breaking 80 day dry spell in Spokane and the surrounding areas.

Table 1. *Observed (Obs.) and departure (Dept.) total precipitation values for Washington climate divisions in 2017. All values are recorded in inches. Departure values are the difference from the 20th century average. The color scale denotes the placement of each period in the yearly climatological rankings from the National Center for Environmental Information. Data sources: National Weather Service Advanced Hydrologic Prediction Service.*

	Jan - Mar		Apr - Jun		Jul - Sep		Oct - Dec		Annual	
	Obs.	**Dept.**	**Obs.**	**Dept.**	**Obs.**	**Dept.**	**Obs.**	**Dept.**	**Obs.**	**Dept.**
West Olympic Coastal	46.06	+5.55	22.21	+6.72	3.82	-5.01	50.20	+6.76	122.3	+14.03
NE Olympic San Juans	8.75	-0.06	5.54	+0.70	0.90	-2.50	13.16	+2.45	28.35	+0.58
Puget Sound Lowlands	18.34	+3.55	9.21	+1.96	1.52	-2.95	21.06	+4.25	50.13	+6.81
E Olympic Cascade Foothills	33.39	+6.80	14.84	+3.15	2.81	-3.70	34.86	+5.86	85.9	+12.11
Cascade Mountains West	40.60	+8.62	15.70	+2.81	3.28	-3.93	40.53	+6.26	100.1	+13.76
East Slopes Cascades	17.23	+3.33	7.00	+1.65	0.96	-1.96	16.42	+1.63	41.61	+4.65
Okanogan Big Bend	6.61	+2.79	4.24	+1.08	0.32	-1.40	4.72	+0.29	15.89	+2.76
Central Basin	5.63	+2.33	2.54	+0.46	0.47	-0.55	4.17	+0.41	12.81	+2.65
Northeastern	10.96	+4.43	6.61	+1.12	0.94	-2.20	7.90	+0.66	26.41	+4.00
Palouse Blue Mountains	10.23	+4.06	4.60	-0.04	1.07	-1.19	8.58	+1.99	24.48	+4.82

Record Driest	**Bottom 10%**	**Bottom 33%**	**Normal**	**Top 33%**	**Top 10%**	**Record Wettest**

From July to September, departure from normal values were in the driest 10% of recorded observations for 8 of 10 climate regions. The Puget Sound Lowlands, the rain shadow region of the Olympics near Sequim and the San Juan Islands experienced their driest summers on record. In October, an upper-air pattern change towards more transient low-pressure systems provided considerable relief to dry, warm conditions throughout the state. From October to December, precipitation was mostly at or slightly above normal for all regions. Many locations on the westside experienced precipitation anomalies above 4”. In all, 2017 ended as the 27th wettest year on record, but trailed last year’s statewide precipitation average of 49.14” by 0.4”.

TEMPERATURE

The average temperature across Washington in 2017 was 46.8°F, or about 0.7°F higher than the 20th century average of 46.1°F. This year was about 1.8°F cooler than 2016 and 3.2°F cooler than 2015, the warmest year on record.

January and February started the year trending towards below average temperatures with anomalies in the Lower Columbia Basin around 10°F – 13°F cooler, and the rest of the state 1°F – 7°F cooler. By March, temperatures rebounded to near normal, with only slightly cooler temperatures in the Northwest counties, Northern Columbia Basin, and the Olympic Peninsula. April was fairly cool and showery, but this was short-lived as May and June experienced slightly above normal temperatures. The summer period of July to September was much warmer with daily average temperature departures of 2°F - 4°F above normal

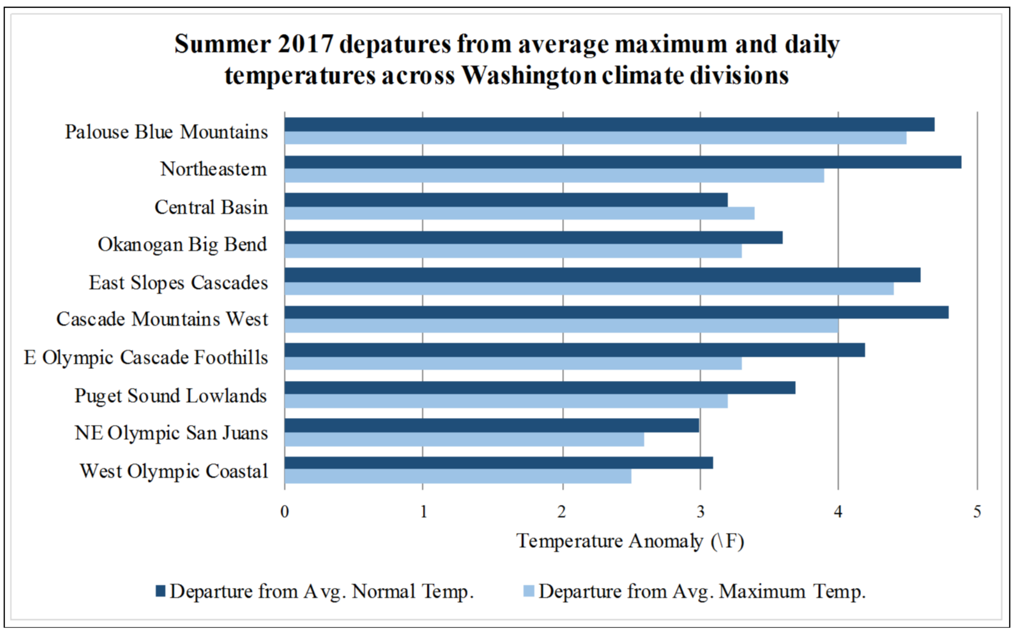


Figure 1. *July – September 2017 departure from normal values for average maximum and daily temperatures. This past summer was characterized by the National Center for Environmental Information as the third hottest summer in Washington for the observational record (2014 and 1998 were hotter).*

(Fig. 1). This was the 3rd warmest summer on record for the state, surpassing both 2016 and 2015 by 3.2°F and 1.4°F, respectively. Largely, this warm period can be attributed to the same blocking ridges of high-pressure over the Pacific that caused Washington's simultaneous precipitation drought. Persistent hot and dry conditions led to average daily maximum temperatures around 82°F - 86°F for much of the eastside and maximum temperature departure values of 3°F - 5°F across all climate regions. The October to December period saw a return to near normal conditions.

SNOWPACK

Snow water equivalent (SWE) measurements (the amount of water content available should snowpack be melted instantaneously) for the 2016 – 2017 winter were greatly improved over both the 2014 – 2015 and 2015 – 2016 winter periods. In November 2016, snowfall accumulations started as lackluster, with most areas throughout Washington showing zero SWE by mid-month due to precipitation measurements between 25 – 50% of normal and 3-7 °F warmer temperatures statewide. By 1 December, the onset of cooler temperatures and increased precipitation in the latter half of November had led to accumulating snowfall for all basins, although many were still below normal when compared to the 1981 – 2010 median. In January 2017, this trend in below average snowpack was mostly reversed as precipitation recovered to near normal values. Snow depth measurements were nearly the same as in 2016 during this time: 100" in the North Cascades, 40" – 60" in the Central Cascades, 70" – 90" in the Southern Cascades and Olympics, and about 15" – 25" in the Blue and Selkirk Mountains of Eastern Washington. From mid-February onwards, persistent cool and moist conditions pushed SWE values well in excess of normal, with every basin reporting between 105 – 163% of normal on 1 May.

Interestingly, SWE departure values continued to increase over the May and June period when snowmelt would generally result in dwindling numbers. April and early May snowfalls continued to pile on snow, resulting in snowpack depths of 120" – 180" in the North Cascades, 70" – 90" in the Central Cascades, 100" – 180" in the Southern Cascades and Olympics, and about 35" – 70" in the Blues and Selkirk Mountains of Eastern Washington on 1 June. Snowpack persisted in the High Cascades through nearly July. Runoff from snowmelt created an extended growing season for agricultural lands and a substantial grass crop in Eastern Washington forests, providing ample fuel for wildfires later in the summer. Overall, when looking back at 2015 and 2016, 2017 truly saw a fantastic improvement in snowpack (consider these statewide average departures from normal for 1 June: 2015 – 7.7%; 2016 – 41.9%; and 2017 – 142.7%).

WIND AND ICING EVENTS

According to the Office of the Washington State Climatologist, there were no notable wind storms during 2017. There were also no major ice storms which would have caused significant damage to area forestlands.

DROUGHT

Following the 2015 severe drought period in Washington, drought conditions improved greatly through 2016. By November, there were no major drought concerns statewide. This lasted until mid-summer 2017, when the presence of a strong high pressure system set up over the Pacific Coast, leading to zero or negligible precipitation statewide for the month. Abnormally dry areas were mostly confined to the lee slopes of the Cascades from Chelan southward to the Oregon border and the eastern Blue Mountains. By August, yet another upper-air blocking pattern had set up, amplifying the statewide precipitation deficit. This resulted in much of the state, from Olympia eastward to the Idaho border, to be classified as abnormally dry or experiencing moderate drought. Through September, precipitation anomalies continued to remain mostly 0 – 20% of normal, prompting the USDA to classify the entire state as experiencing moderate drought. Rains finally came in early October, alleviating any concerns for a large-scale prolonged drought, although moderate drought conditions would persist in Okanogan, Ferry, and Stevens Counties through the remainder of the month. October and November precipitation values were at or slightly above normal, and on 21 November 2017, the state was reclassified with no drought concerns.

Wildfire and Firewise

According to data compiled by the Northwest Coordination Center (NWCC) and Washington Department of Natural Resources (WDNR), wildfires burned 381,707 acres in WA during the 2017 fire season which spanned April to November (Fig. 2). This total acres burned amount

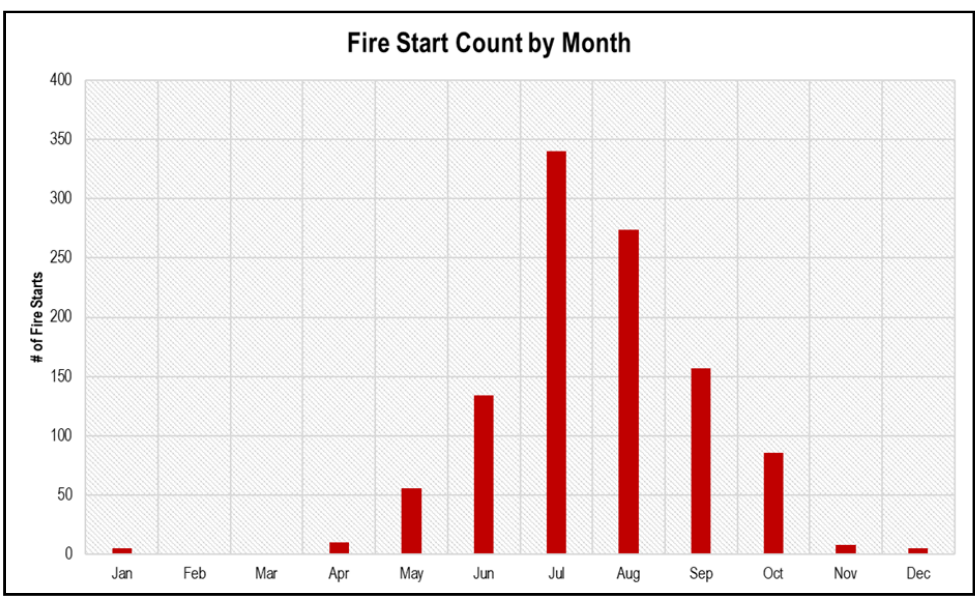


Figure 2. *Number of fire starts by month in 2017 in Washington.*

is easily considered an above-average wildfire season with nearly 100,000 (30%) more acres burned compared to last season (2016 - 293k acres). A total of 1077 fires occurred during the year of which 57 were considered “large fires” per the NW Coordinating Group (NWCG) definition of having burned greater than 100 acres of forestland or 300 acres of brush/grasses (Fig. 3). The average large fire size for 2017 was approximately 7,200 acres. Estimates for the wildfire causes in 2017 were 6% caused by lightning, 17% undetermined, and the remaining 77% human-caused. The single largest wildfire in 2017 was the Diamond Creek Fire. It started by lightning July 23rd in Okanogan County on USFS land and burned northward into Canada over a long period from late July to the end of October. The Diamond Creek fire totaled 128,272 acres burned – 97,140 acres in the US and 31,132 in Canada, the US amount eventually constituted 25% of the total acres burned across the whole State for the season. Other notable large wildfires in order of their sizes were the Norse Peak fire with 52,056 acres and the Jolly Mountain fire with 36,808 acres – both of these large fires, along with two others, started by lightning on August 11th, and also comprised nearly 25% of the total acres burned in the state.

FIREWISE

To help lessen the impact and reduce risk of catastrophic wildfire, 21 recognized Firewise communities were added across the State and 128 others were maintained in active status.

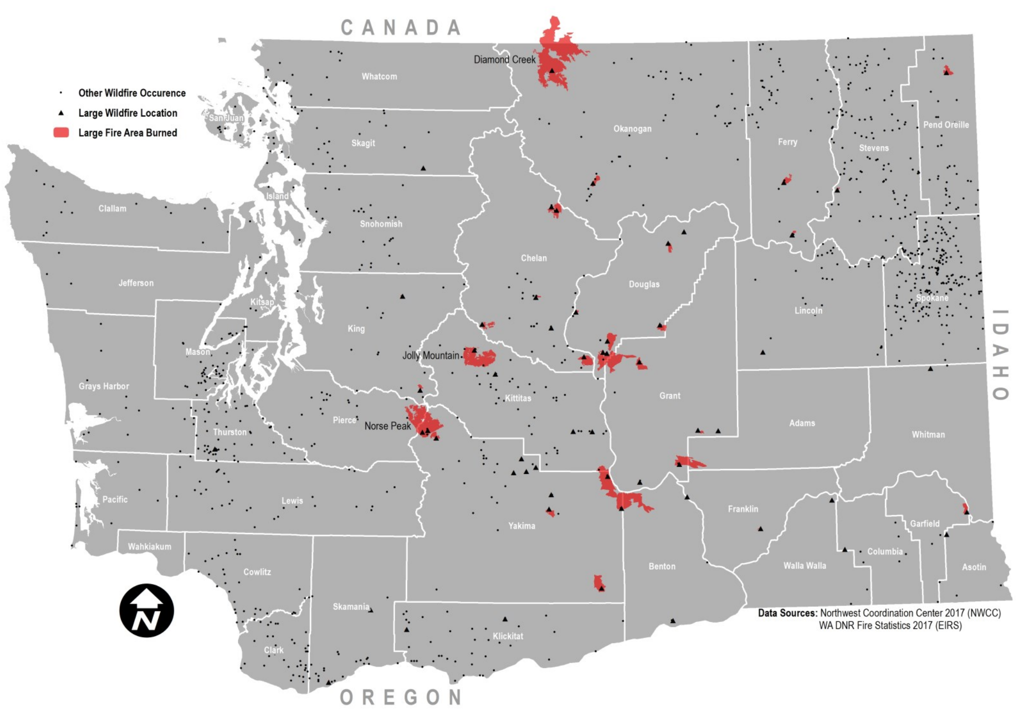


Figure 3. *Location of wildfires that occurred in Washington in 2017. Map by Kirk Davis, Washington DNR.*

Aerial Detection Survey

Methods

The annual insect and disease aerial detection survey (ADS) in Washington was conducted by the USDA Forest Service (USFS) in cooperation with WDNR. The survey is flown at 90-150 mph at approximately 1,500 feet above ground level in a fixed-wing airplane (Fig. 4). Two observers (one on each side of the airplane) look out over a two-mile swath of forestland and mark on a digital sketchmapping computer any recently killed or defoliated trees. They then code the agent that likely caused the damage (inferred from the size and species of trees and the pattern or “signature” of the damage) and the number of trees affected. Photos are rarely taken. It is very challenging to accurately identify and record damage observations at this large scale. Mistakes occur. Sometimes the wrong pest is identified. Sometimes the mark on the map is off target. Sometimes damage is missed. Our goal is to correctly identify and accurately map within ¼ mile of the actual location at least 70% of the time. In areas with heavy mortality, on-ground observations of trees per acre (TPA) killed are commonly 2-3 times greater than estimates made from the air.

ADS observers are trained to recognize various pest signatures and tree species. Newer satellite photography showing recent management activity allows observers to place the damage polygons more accurately on their computer screens. There is always at least one observer in the plane who has three or more years of sketchmapping experience.

Each damage area (polygon) is assigned a code for the damage agent. These codes are defined in the legend of the aerial survey maps. The agent code is followed by number of trees affected; number of trees per acre affected; or intensity of damage (L-Light, M-Moderate, H-Heavy). If more than one agent is present in a polygon, codes are separated by an exclamation point (!). When interpreting data and maps, do not assume that the mortality agent polygons indicate every tree is dead within the area. Depending on the agent code modifier, only a small proportion of trees in the polygon may actually be recently killed.

The perimeters of areas burned by wildfire are added to aerial survey maps the year of the fire. The year after the fire, dead trees are not recorded within the fire perimeter. This is because from the air it can be difficult to distinguish mortality caused by the fire from mortality caused by insects or disease. The second summer after the fire, when direct effects of the burn have mostly subsided, pests can be credited with the newest tree damage, and that damage is counted in the aerial survey totals.

Ben Smith, USDA Forest Service

Figure 4. *U.S. Fish and Wildlife aircraft used for portions of the Washington aerial survey in 2017.*

2017 Aerial Survey Conditions

Temporary flight restrictions around three large wildfires that burned late into the season in 2017 prevented aerial observers from surveying approximately 156,000 acres. The largest of these was the Diamond Creek fire in north central Washington along the Canadian border in addition to the Norse Peak fire east of Mt. Rainier and the Bridge Creek fire on the Colville Indian Reservation (Fig. 5). 2017 was the first year observers mapped in 1.5 million acres that were affected by wildfires in 2015. Areas burned by wildfire are not mapped until the second year following the fire because fire-related mortality cannot be distinguished from other types of damage from the air. Persistent wildfire smoke in Ferry, Stevens, and Pend Oreille counties likely reduced the amount of visible defoliation signatures, such as western spruce budworm and larch needle blight activity, recorded in the this area. In most years, the forested area around Joint Base Lewis-McCord (JBLM) is not flown by aerial survey due to challenges with airspace coordination. Through coordination with JBLM staff, aerial observers have successfully surveyed 180,000 acres of forest land around the base in 2016 and 2017.

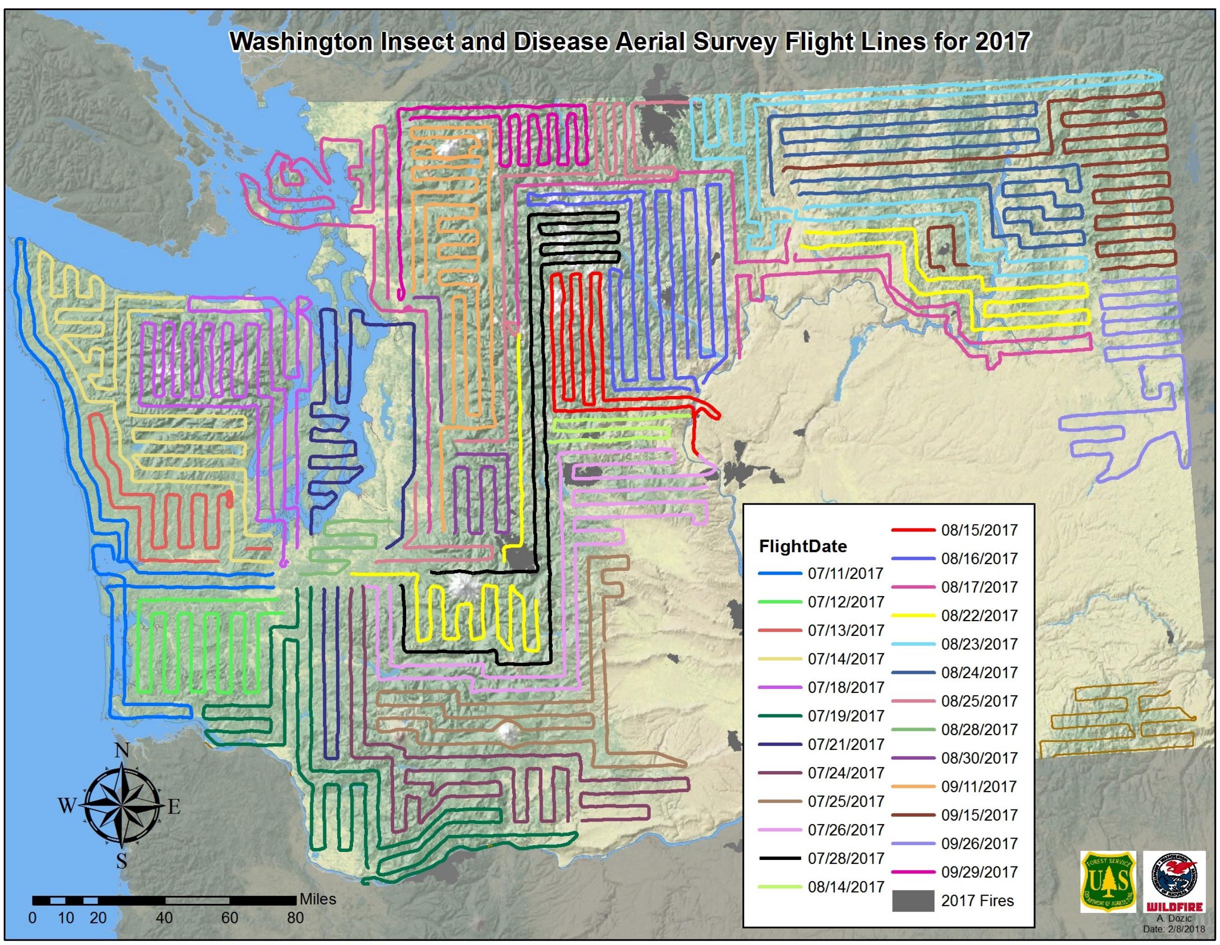


Figure 5. *Washington insect and disease aerial survey flight lines for 2017. Map by: Aleksandar Dozic, Washington DNR.*

2017 Aerial Survey Summary Maps

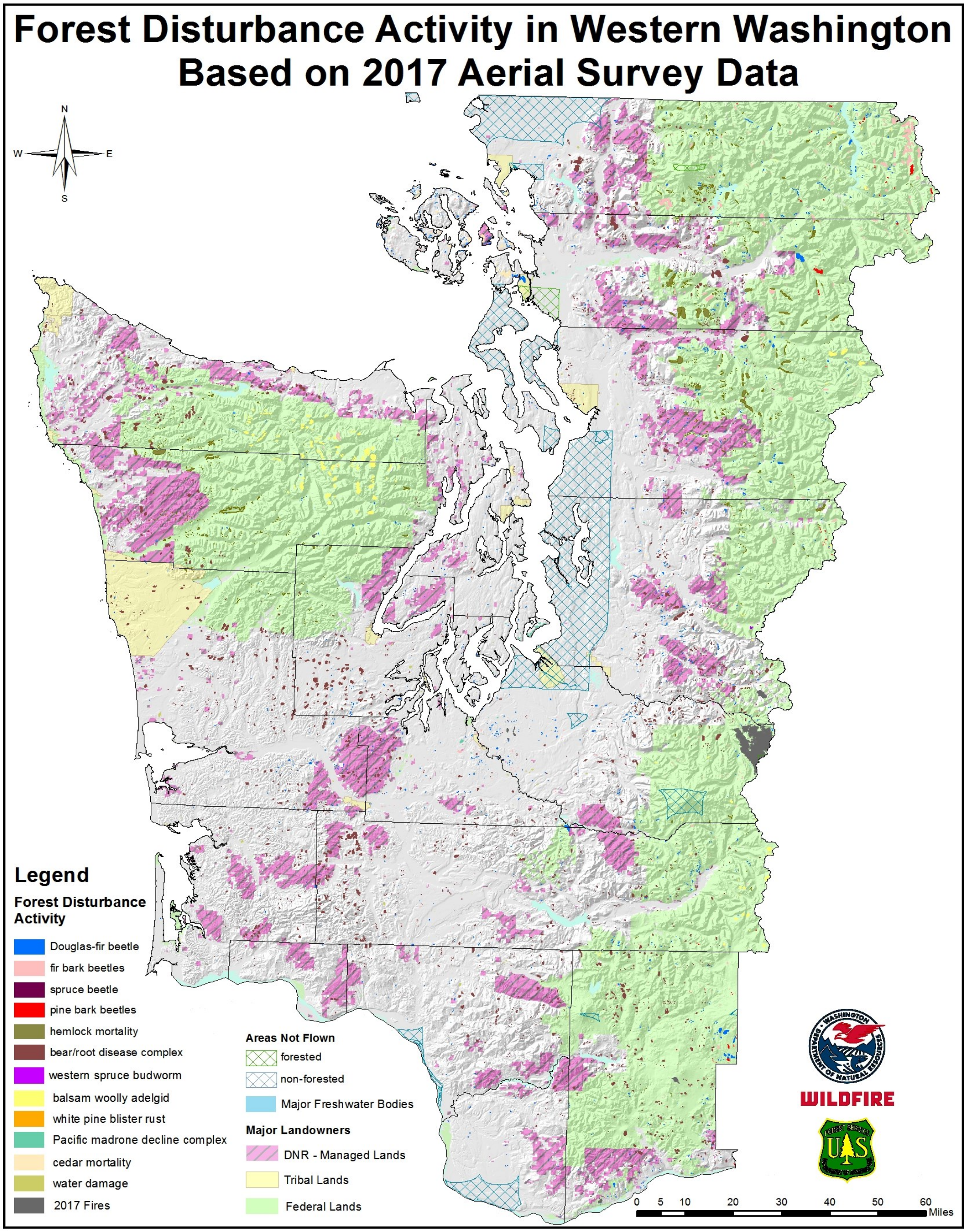


Figure 6. *Forest disturbance map of western Washington composed from 2017 aerial survey data. Map by: Aleksandar Dozic, Washington DNR.*

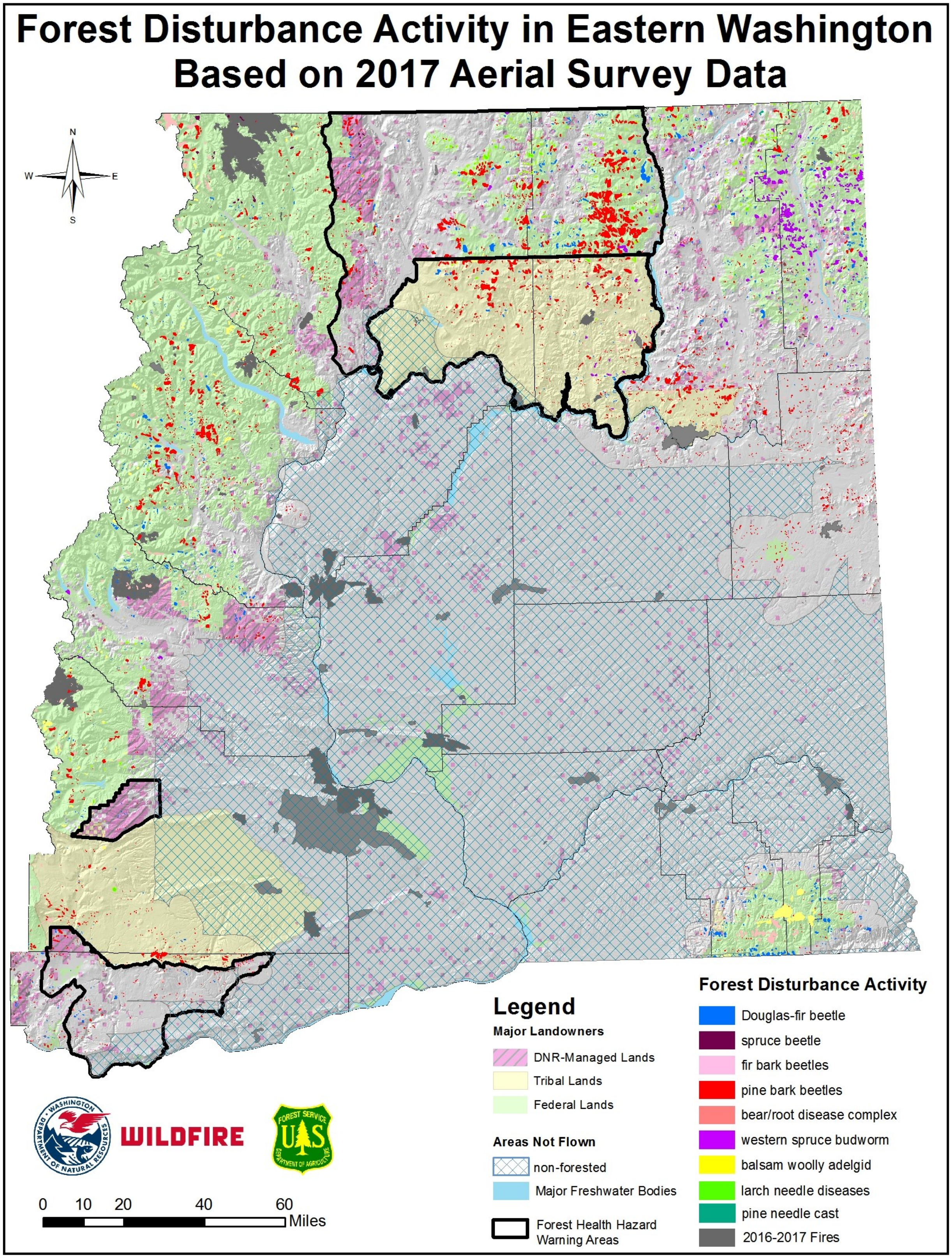


Figure 7. *Forest disturbance map of eastern Washington composed from 2017 aerial survey data.*
Map by: Aleksandar Dozic, Washington DNR.

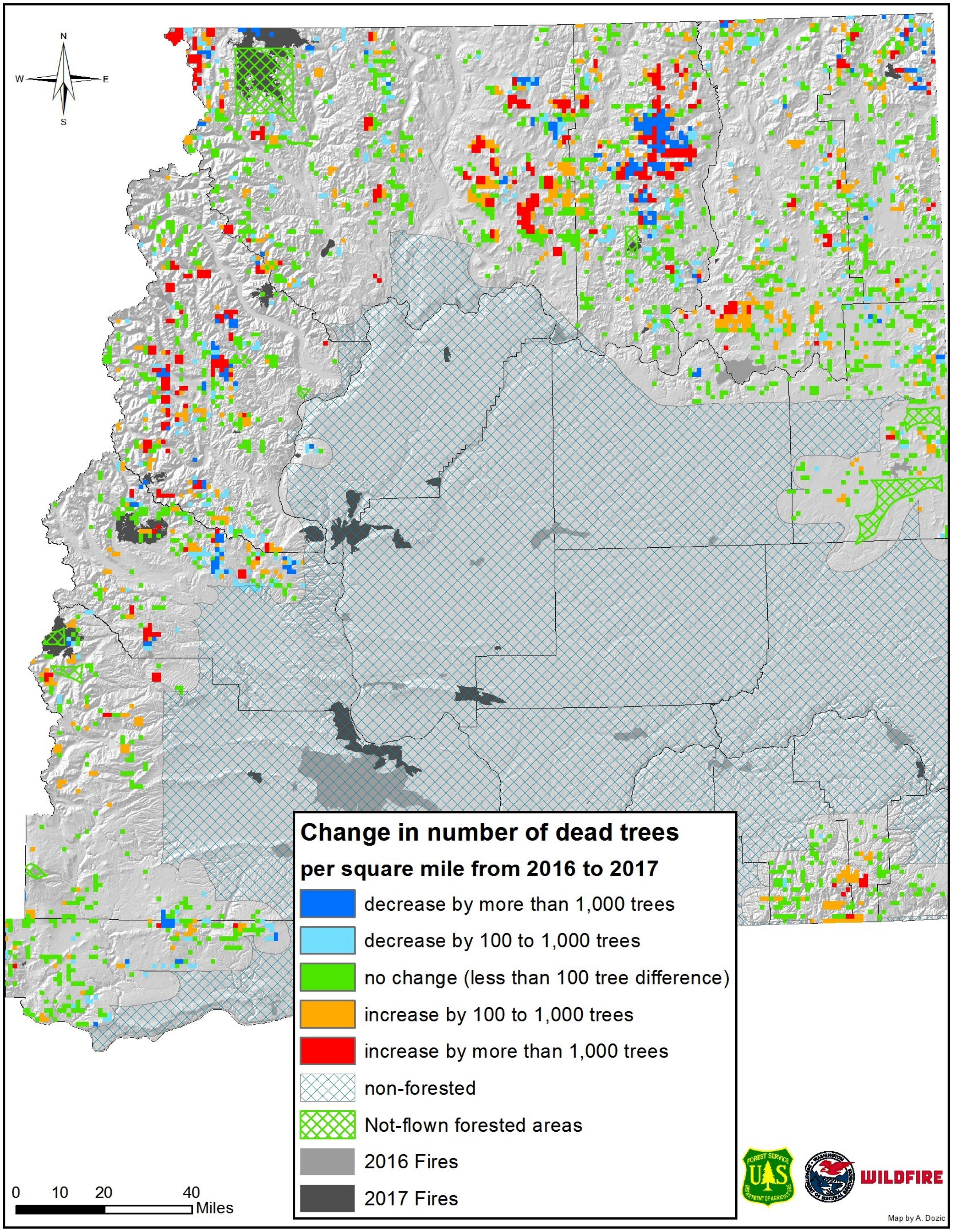


Figure 8. *Change in tree mortality levels recorded by aerial survey in eastern Washington between 2016 and 2017. Map by: Aleksandar Dozic, Washington DNR.*

20-Year Forest Health Strategic Plan

A Strategic Plan for Eastern Washington

The Washington State Department of Natural Resources has a core commitment to lead statewide forest health efforts. In Fall 2017, DNR released a 20-Year Forest Health Strategic Plan for eastern Washington. The plan calls for maximizing the effectiveness of forest health treatments by prioritizing management activities across watersheds. DNR developed the plan collaboratively with over 30 organizations representing a diverse array of expertise and interests. The plan consists of five goals and associated strategies designed to reduce the risk of uncharacteristic wildfires and create resilient forests.

The Vision

Washington's forested landscapes are in an ecologically functioning and resilient condition and meet the economic and social needs of present and future generations.

The Mission

Restore and manage forested landscapes at a pace and scale that reduces the risk of uncharacteristic wildfire and increases the health and resilience of forest and aquatic ecosystems in a changing climate for rural communities and the people of Washington state.

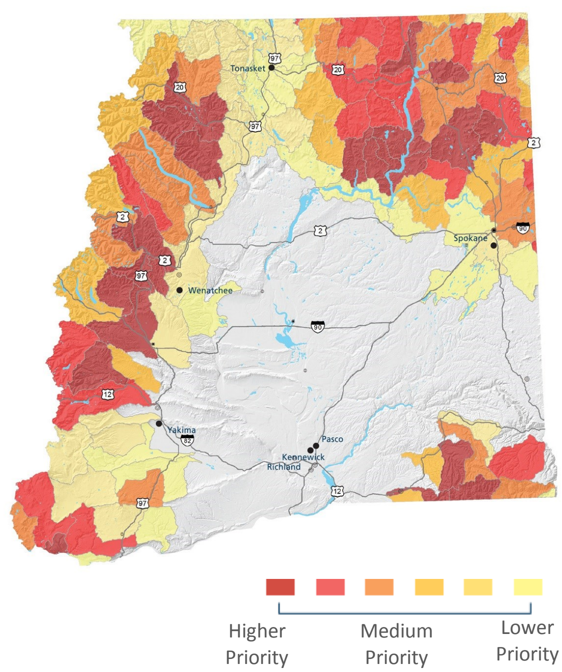
Moving Forward Together

DNR will be working with the newly formed Forest Health Advisory Committee, agencies and other partners to implement the plan.

GOAL 1

Conduct 1.25 million acres of scientifically sound, landscape-scale, cross-boundary management and restoration treatments in priority watersheds to increase forest and watershed resilience by 2037.

EASTERN WASHINGTON PRIORITY WATERSHEDS



Isolated treatments are not doing enough to improve the health of our forests. To make meaningful progress we must focus on entire watersheds and because there are not enough resources to address every watershed at once, we must prioritize.

For more information on the plan, please visit: dnr.wa.gov/ForestHealthPlan

GOAL 2

Reduce risk of uncharacteristic wildfire and other disturbances to help protect lives, communities, property, ecosystems, assets and working forests.

DENSE FOREST WITH LADDER FUELS AND NO DEFENSIBLE SPACE

AFTER TREATMENT THERE ARE WIDELY SPACED TREES WITH LESS FUEL

FIRE REMAINS ON THE GROUND, LARGE TREES SURVIVE AND RISK TO STRUCTURES IS REDUCED

Wildfires will continue to be a major disturbance. Yet, each year a growing expanse of treated watersheds will begin to benefit from less intense wildfires.

GOAL 3

Enhance economic development through implementation of forest restoration and management strategies that maintain and attract private sector investments and employment in rural communities.

Tapash Collaborative forest health thinning near Cle Elum

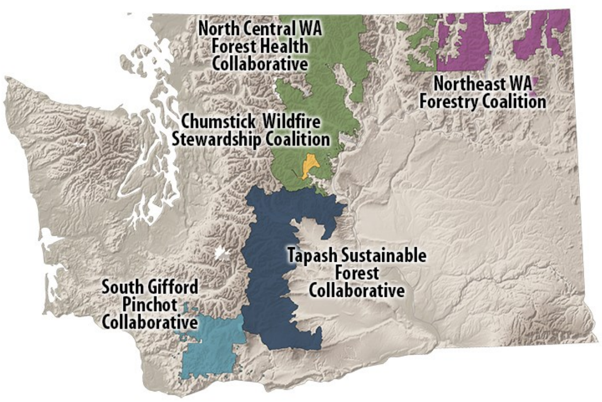
Cross-laminated timber classroom

Forest Health can be an economic catalyst. By adding value to restoration by-products and small-diameter timber, we can help pay for needed treatments and provide economic opportunities for rural communities. Thinning projects can increase timber supply to existing and new mills, and spur related investments.

GOAL 4

Plan and implement coordinated, landscape-scale forest restoration and management treatments in a manner that integrates landowners objectives and responsibilities.

EASTERN WASHINGTON FOREST COLLABORATIVES



Eastern Washington collaboratives support cooperative forest health restoration.

GOAL 5

Develop and implement a forest health resilience monitoring program that establishes criteria, tools and processes to monitor forest and watershed conditions, assess progress and reassess strategies over time.

Monitoring of forest health conditions and tracking progress is critical to ensuring the success of the plan and determining continued investments in forest health treatments.

Insects

Bark Beetles

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

Pine bark beetle activity recorded by aerial survey increased in 2017 to approximately 191,000 acres from 126,000 acres in 2016 (Fig. 9). The number of pine trees estimated to have been killed by pine bark beetles was 2.47 million in 2017; a much higher intensity of mortality than the estimated 1.74 million trees killed in 2016 (Table 2).

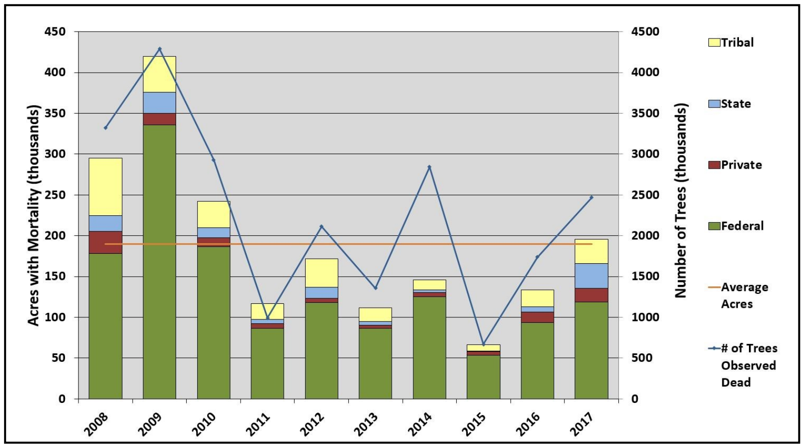


Figure 9. *Ten year trend for total acres and number of trees affected by pine bark beetles in Washington.*

Pine mortality due to **mountain pine beetle** (MPB, Fig. 11) was recorded on 165,200 acres, an increase from 2016 but still below the ten-year average of 174,000 acres. The inclusion of burned areas not mapped in 2015 may have contributed to the increase. Relative to 2016, MPB -caused mortality increased for all hosts: lodgepole pine (126,400 acres), ponderosa pine (46,500 acres), whitebark pine (1,400 acres), and western white pine (170 acres). The 46,500 acres with ponderosa mortality attributed to MPB was the highest level since 2008. The most concentrated areas of lodgepole and ponderosa pine mortality occurred in the Colville National Forest in northern Ferry County and eastern Okanogan County. Mortality was also elevated in Chelan County and within the Okanogan-Wenatchee National Forest (Figs. 7 & 8).

Table 2. 2017 statewide acres affected and estimated number of pine bark beetle-killed trees.

Beetle species	Host(s)	Acres with mortality*	Estimated number trees killed
mountain pine beetle	lodgepole pine	126,400	2,091,000
mountain pine beetle	ponderosa pine	46,500	204,700
mountain pine beetle	whitebark pine	1,400	5,900
mountain pine beetle	western white pine	170	330
western pine beetle	ponderosa pine	18,700	151,800
pine engravers (*Ips* species)	all pines	2,500	14,150
	Totals:	191,000 (*footprint*)*	2,467,880

*Multiple host species can be recorded in a single area, therefore the sum of acres for all hosts is greater than the total footprint affected.

Areas with mortality of ponderosa pines due to **western pine beetle** (WPB) increased to 18,700 acres, the highest level since 2006. Severe summer drought conditions and wildfires of 2015 were likely a contributing factor in development of these outbreaks. The highest concentrations of WPB-caused mortality were in the southern areas of Okanogan, Ferry, and Stevens counties; and throughout Spokane County (Fig. 10). Scattered areas with mortality were also recorded in Klickitat and Yakima counties. The 2,500 acres with pine mortality attributed to ***Ips* pine engravers** was also recorded at the highest level since 2006. Pine engraver-caused mortality is often higher following periods of drought. Outbreaks of WPB and pine engraver observed in 2006 also followed another period with severe droughts in eastern Washington.

Glenn Kohler, Washington DNR

Figure 10. *Group of ponderosa pines killed by western pine beetle on Loup Loup Pass.*

Justin Hof, USDA Forest Service

Figure 11. *Lodgepole pine mortality from mountain pine beetle seen from the air.*

California Fivespined Ips (*Ips paraconfusus* Lanier)

California fivespined Ips (CFI), a pine engraver beetle native to Oregon and California, was first detected in Washington State in 2010, where it has either expanded its range or re-occupied a historic range. Localized outbreaks of CFI continued to cause unusually high levels of ponderosa pine mortality in areas along the Columbia River Gorge in Klickitat and Skamania counties. In 2017, a new area in Benton County with CFI-caused mortality was confirmed in several mature ponderosa pines on private land.

WDNR has coordinated a statewide survey since 2011 to determine the extent of CFI range throughout Washington (Fig. 12). With cooperator assistance, both CFI and *Ips pini* baited traps were deployed at 10 locations in 7 counties in 2017. CFI was collected for the first time in pheromone traps in Kennewick (Benton County) and north of Glenwood (Yakima County) in 2017. To date CFI has been collected in nine counties in WA (Benton, Clark, Cowlitz, Klickitat, Lewis, Pierce, Skamania, Thurston, and Yakima). From Vancouver, the known range of CFI in Washington extends 100 miles north to Pierce County and 180 miles east to Benton County. CFI-caused ponderosa mortality has not been observed in western Washington and trap catches have been relatively low.

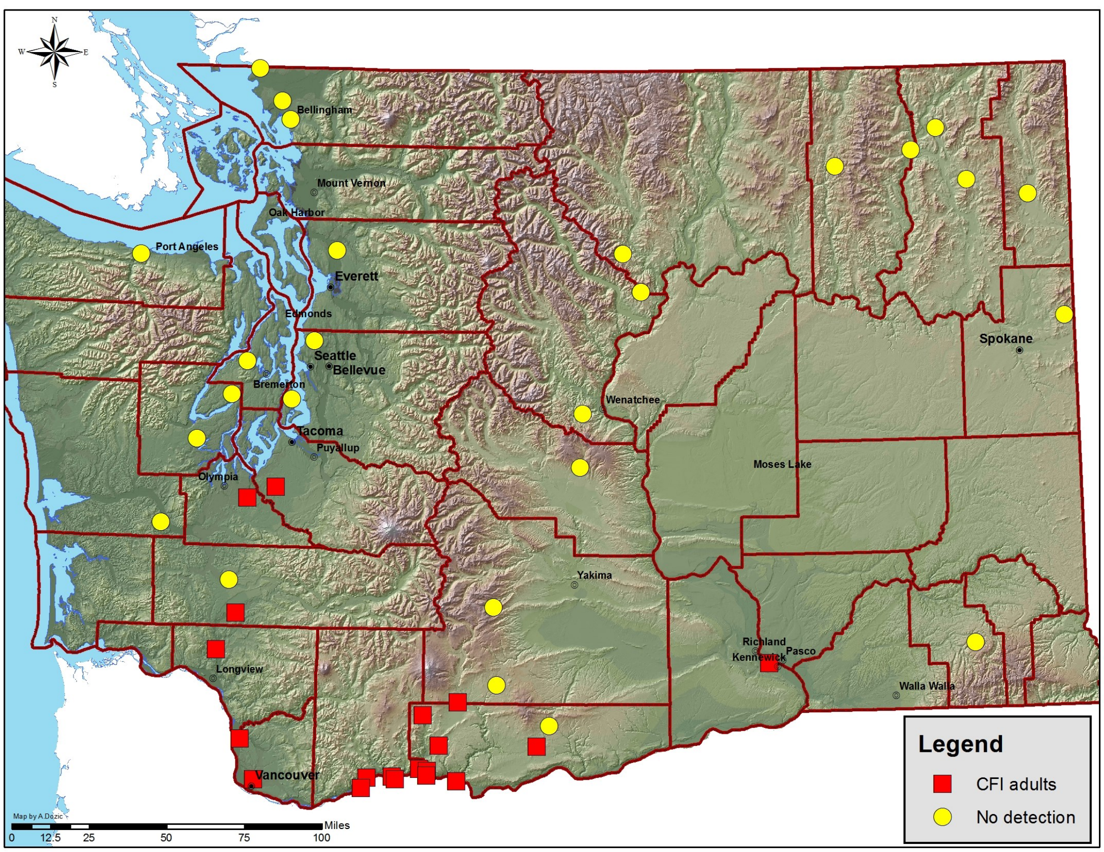


Figure 12. *California fivespined Ips monitoring trap locations in Washington, 2010-2017.*

Douglas-fir Beetle (*Dendroctonus pseudotsugae* Hopkins)

Approximately 48,900 acres with Douglas-fir beetle (DFB, Fig. 13) caused mortality were observed statewide in 2017, up from 30,600 acres in 2016 (Fig. 14). This was the highest level of DFB mortality since 2009, the peak year of outbreaks in western WA. Scattered areas of DFB-caused mortality were detected throughout the east slopes of the Cascades, the Blue Mountains, and in northeast Washington.

The highest concentrations were in Asotin, Columbia, Skamania, Klickitat, Kittitas, Chelan, Stevens, and Ferry counties. Increases near the Columbia River Gorge and Stevens County may be associated with 2015 windstorms. Increases in other areas may be related to 2015 drought and wildfires in addition to effects of defoliation by the western spruce budworm in the central Cascades.

Melissa Fischer, Washington DNR

Figure 13. *Boring dust (frass) indicating attack by Douglas-fir beetle.*

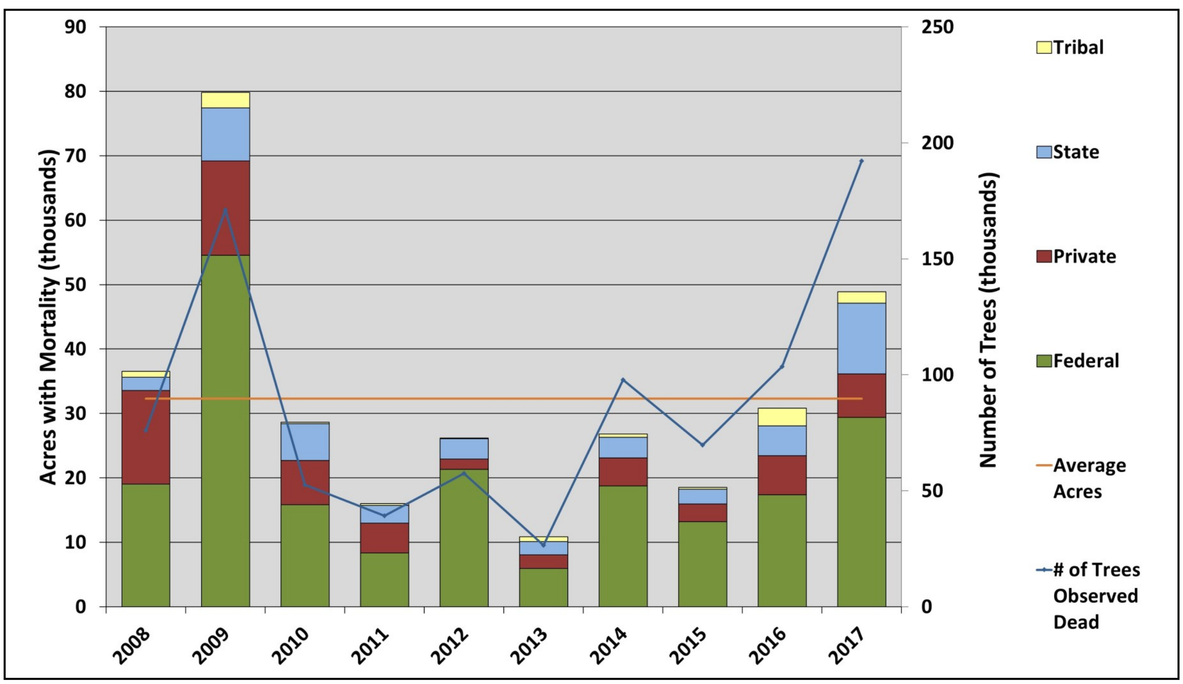


Figure 14. *Ten year trend for total acres and number of trees affected by Douglas-fir beetle in Washington.*

Secondary Bark Beetles in Douglas-fir
(*Scolytus monticolae* (Swaine), *Scolytus unispinosus* LeConte, and *Pseudohylesinus nebulosus* (LeConte))

Figure 15. *Damage to Douglas-fir from secondary bark beetles.*

Secondary bark beetles species are rarely the cause of mortality in mature trees, but can attack trees stressed by other factors, such as drought, root disease, or attack by more aggressive bark beetle species (Fig. 15). The Douglas-fir engraver, Douglas-fir pole beetle, and *Scolytus monticolae* are secondary bark beetles that commonly build-up in Douglas-fir logging slash and attack small Douglas-fir trees and the tops and branches of larger trees. These attacks are often more successful and the damage more noticeable during drought periods. The three species are frequently found together within the same tree and are difficult to distinguish based on their egg and larval gallery patterns (Fig. 16).

In 2016, damage due to these species increased to the highest level recorded in the history of the Washington aerial survey, an increase was likely due to the 2015 drought. In 2017, secondary bark beetle damage was observed on approximately 1,000 acres during the aerial survey, down from 4,100 acres in 2016. Additional areas with secondary bark beetle damage in Douglas-fir were observed from the ground in southern Stevens County in late fall, after the survey was flown. Lack of precipitation in eastern Washington for over 80 days during the summer months likely contributed to the continuation of damage caused by these species. Possibly related to the summer drought, Douglas-fir trees with fading crowns were observed in some areas of northeast Washington in winter of 2017-2018.

Figure 16. *Douglas-fir pole beetle gallery.*

Fir Engraver (*Scolytus ventralis* LeConte)

Fir engraver can attack all species of true fir (*Abies*) in Washington, but the primary hosts in Washington are grand fir and noble fir (Fig. 17). Fir engraver caused mortality occurred on approximately 46,000 acres in 2017, the highest level since 2010, but still under the ten-year average of 60,500 acres (Fig. 18). Recent drought conditions are likely an important driver of the increase in addition to effects of defoliation by the western spruce budworm in the central Cascades. The most affected areas were in the Okanogan-Wenatchee National Forest in Kittitas and Chelan counties; in the Colville and Spokane Indian Reservations in southern Ferry and Stevens counties; and around the Colville National Forest in Pend Oreille County and northern Spokane County.

Justin Hof, USDA Forest Service

Figure 17. *Grand fir (red crowns) killed by fir engraver and ponderosa pine (orange crowns) killed by western pine beetle in 2017.*

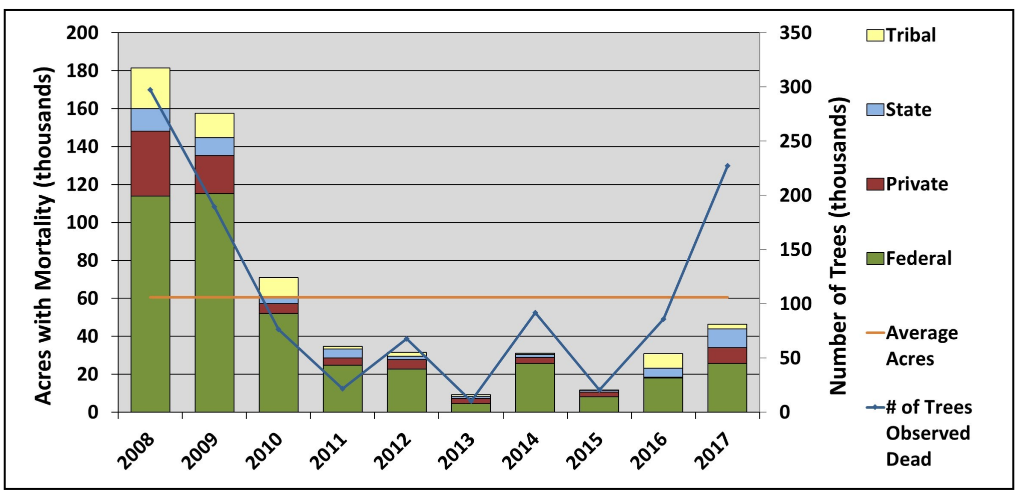


Figure 18. *Ten year trend for total acres and number of trees affected by fir engraver in Washington.*

Western Balsam Bark Beetle (*Dryocoetes confusus* Swaine)

Western balsam bark beetle (WBBB), often in conjunction with balsam woolly adelgid, is an important driver of subalpine fir mortality in high elevation forests of Washington. The 26,000 acres with WBBB-caused mortality in 2017 was a significant increase from the 9,200 acres observed in 2016, and the highest level since 2008.

Spruce Beetle (*Dendroctonus rufipennis* Kirby)

For over a decade, spruce beetle outbreaks have had significant impacts to high elevation stream bottom stands of Engelmann spruce in western Okanogan and eastern Whatcom counties. Mortality due to spruce beetle decreased to approximately 10,600 acres in 2017, the lowest level in ten years (Fig. 20). However, new areas with mortality were detected in northwest Okanogan County along the Cascade crest near the Canadian border. This area was not ground checked due to challenges with late-season wilderness access. However, aerial observers in British Columbia confirmed a spruce beetle outbreak across the border (Fig. 19). The area affected by spruce beetle in north-central Okanogan County decreased significantly in 2017. Ground checks in areas around the Loomis State Forest and eastern Pasayten Wilderness indicated the majority of damage in the area was old mortality.

Figure 19. *Spruce beetle-caused mortality in Engelmann spruce in British Columbia along the Cascade crest near the U.S. border.*

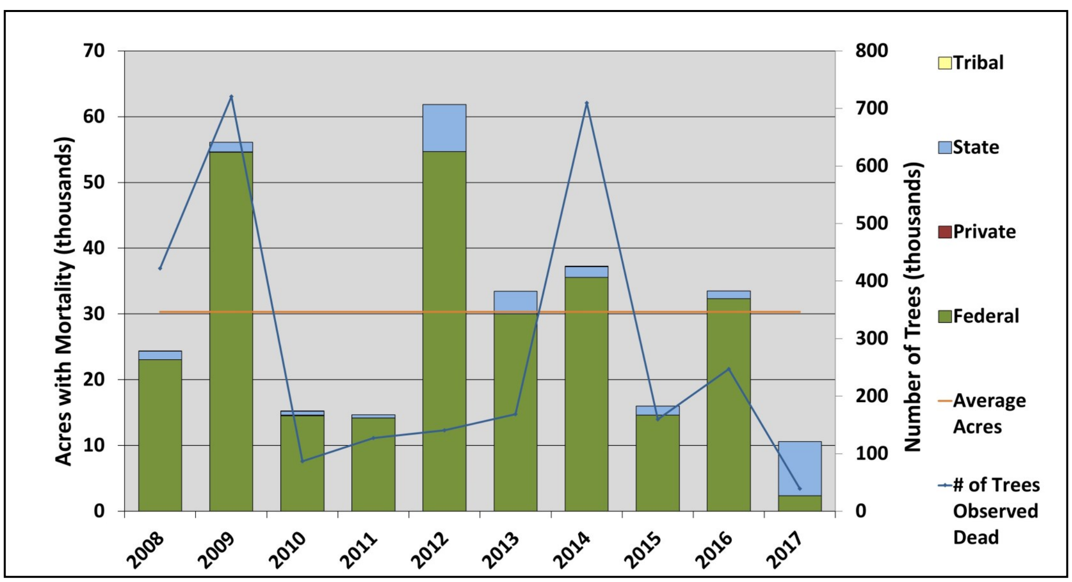


Figure 20. *Ten year trend for total acres and number of trees affected by spruce beetle in Washington.*

Defoliators

Western Spruce Budworm (*Choristoneura freemani* Razowski)

Glenn Kohler, Washington DNR

Figure 21. *Recovery of growth on western spruce budworm damaged Douglas-fir after collapse of outbreak in Kittitas County, 2017.*

In 2017, approximately 40,400 acres with western spruce budworm (WSB) defoliation were recorded in Washington, primarily in the northeast corner of the state. This was a small decrease from the 46,300 acres recorded in 2016 but well below the ten-year average of 272,000 acres (Fig. 22). The increase was significant for Pend Oreille and northern Stevens counties, an area that has had only scattered activity since 2012. Haze from wildfire smoke in this region during survey flights made it challenging to detect the signature of light defoliation in certain lighting conditions, possibly resulting in underestimation of acres affected. The outbreak in the central Cascades (Kittitas and Chelan counties) that lasted over a decade has collapsed and damaged trees have begun to recover (Fig. 21). Very little new defoliation was recorded in this area and caterpillar activity was less evident. Douglas-fir beetle and fir engraver caused mortality has increased in the area, likely related to defoliation stress and the 2015 drought.

WSB pheromone traps were placed at 165 locations across eastern WA (Fig. 23). Trap results in eastern Okanogan and northern Ferry counties indicate light to moderate defoliation expected in 2018. Trap catches in Stevens and Pend Oreille counties remain too low to predict defoliation levels for 2018, likely because many are located outside the scattered defoliation areas.

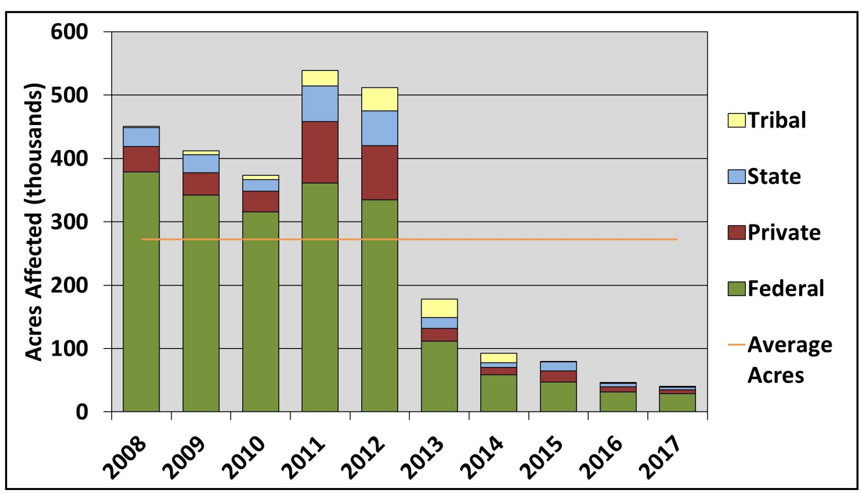


Figure 22. *Ten year trend for total acres affected by western spruce budworm in Washington.*

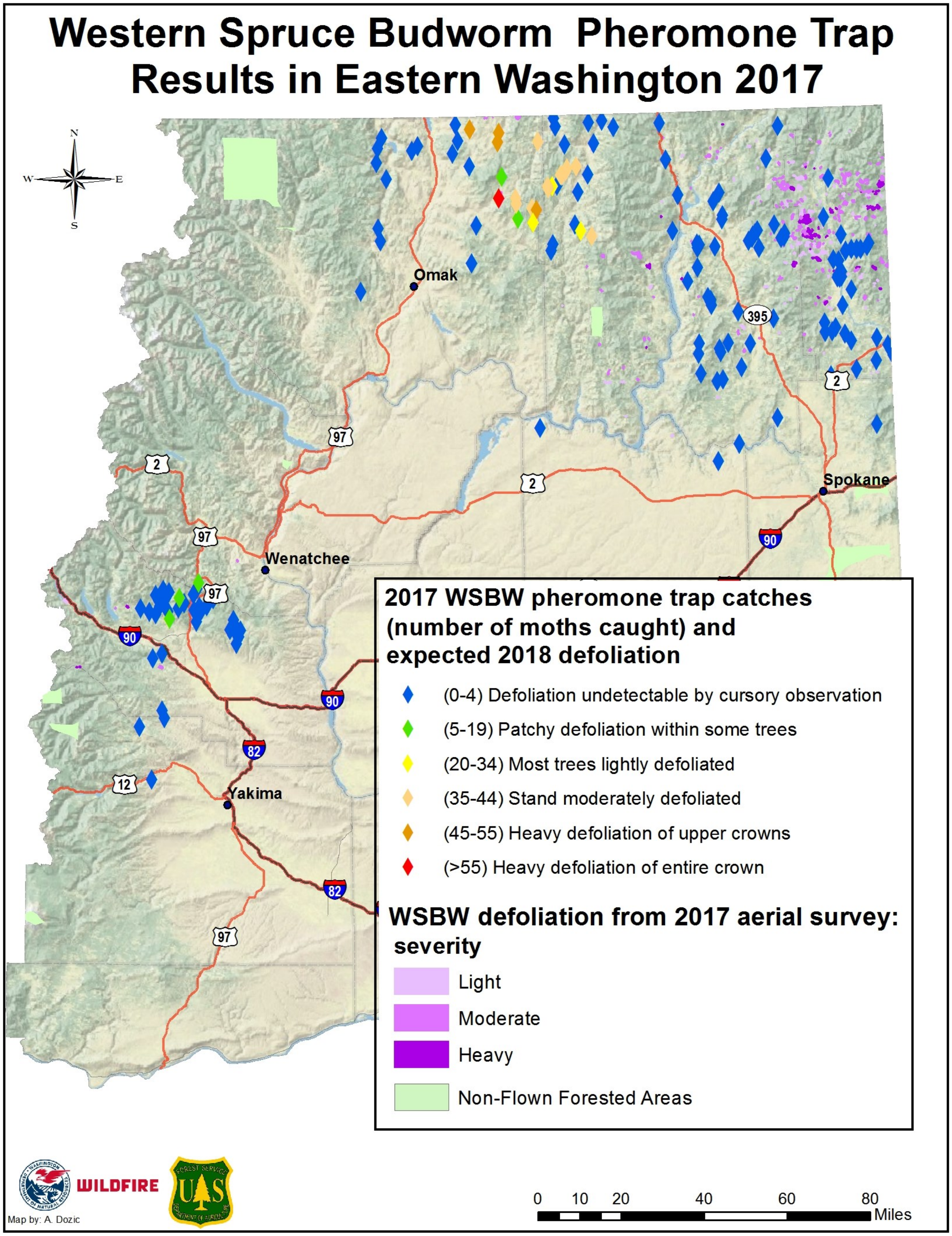


Figure 23. *Western spruce budworm pheromone trap catch results for 2017, expected 2018 defoliation and defoliation detected by the 2017 aerial survey. Map by: Aleksandar Dozic, Washington DNR.*

Douglas-fir Tussock Moth (*Orgyia pseudotsugata* McDunnough)

There was no Douglas-fir tussock moth (DFTM) defoliation recorded in 2017. The last year with any significant defoliation was in 2012 in the Umatilla National Forest in the Blue Mountains. The interagency network of "Early Warning System" pheromone traps at approximately 250 locations in Washington continues to be monitored annually. Trap catches have increased in several areas of central and north-central Washington during 2016 and 2017, which may indicate higher likelihood of defoliation occurring in the next few years (Fig. 24 & 28).

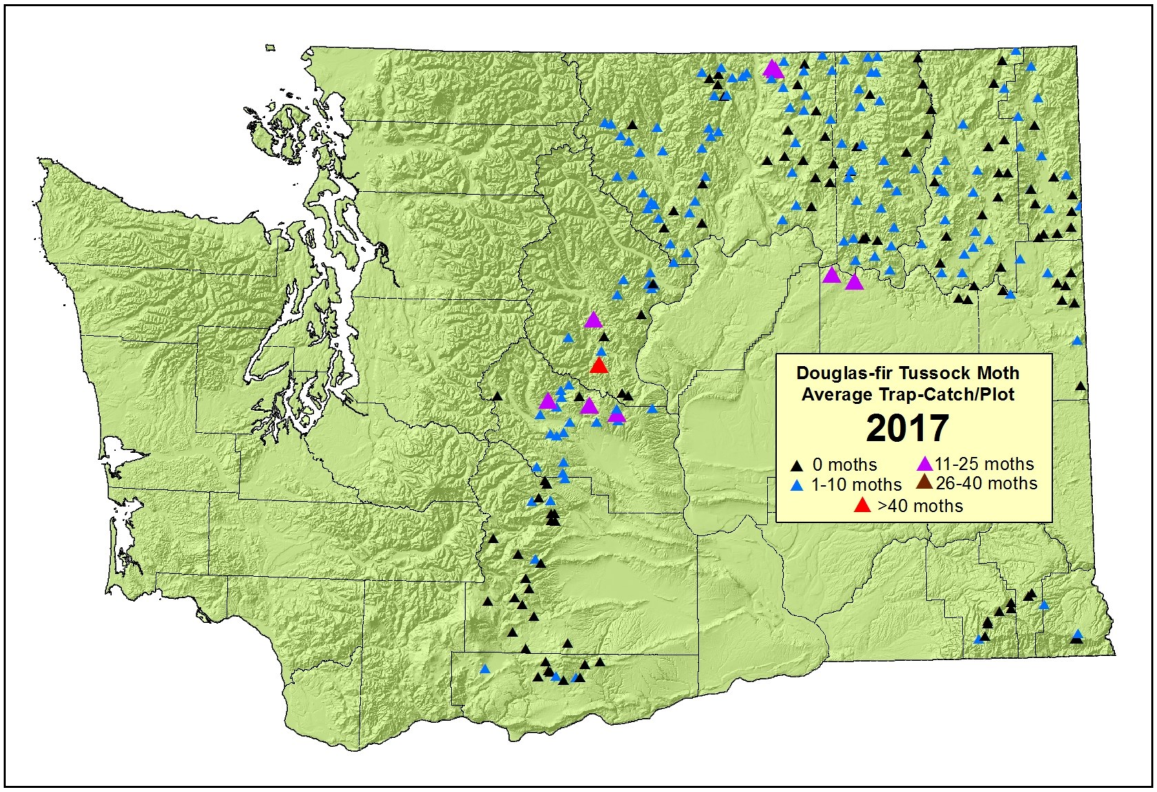


Figure 24. *Douglas-fir tussock moth pheromone trap catch results for Washington in 2016.*
Map by: Zack Heath, USDA Forest Service.

Karen Ripley, USDA Forest Service

Figure 25. *Male Douglas-fir tussock moth adults collected in a pheromone trap.*

Collections of larvae and egg masses from grand fir and Douglas-fir in forested areas of Kittitas County in 2017 were higher than expected and record high trap catches were recorded at some sites there in 2016 and 2017 (Fig. 25). However, the locations of high trap catches are not always correlated with the location of a future outbreak. An increasing trend in trap catches over a wide area indicates that outbreaks are more likely to occur somewhere in eastern Washington within the next few years.

Although not recorded during the aerial survey, defoliated "sentinel trees" were observed throughout Stevens County in 2017 and have been reported from several other locations (Fig. 27). Sentinel trees are ornamental trees, such as blue spruce, that have been defoliated by DFTM (Fig. 26). This activity often precedes a DFTM outbreak by a year or two. Unfortunately, no relationship has been found between the location of the sentinel trees and the forested areas where the future outbreak will occur.

Melissa Fischer, Washington DNR

Figure 26. *Fifth instar Douglas-fir tussock moth larvae feeding on blue spruce.*

Melissa Fischer, Washington DNR

Figure 27. *Ornamental blue spruce "sentinel trees" defoliated by Douglas-fir tussock moth in 2017.*

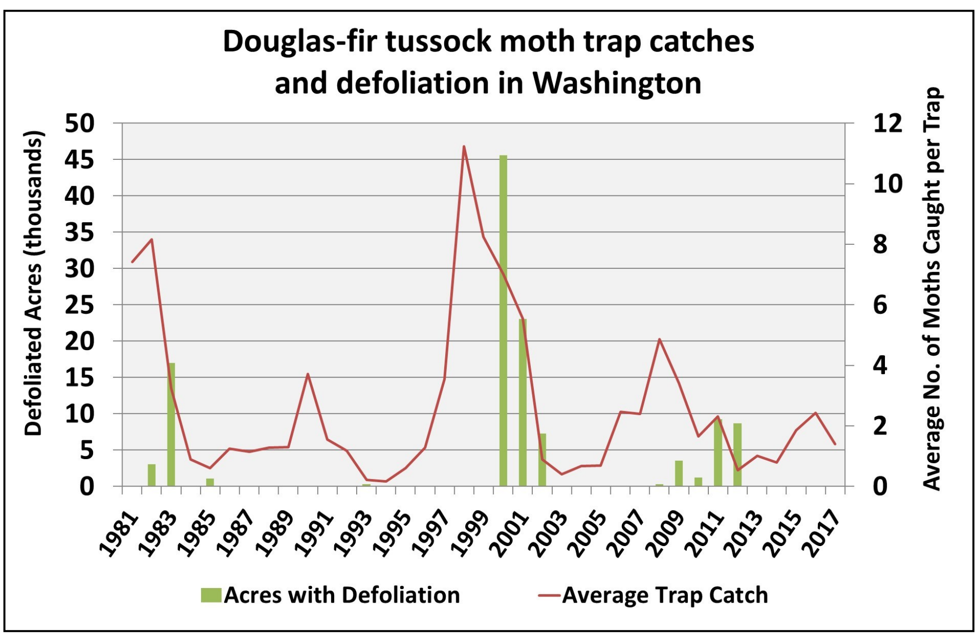


Figure 28. *Douglas-fir tussock moth pheromone trap catches and observed defoliation, 1981 to 2017.*

Larch Defoliation

In 2017, discolored whole crowns of western larch were observed on approximately 18,000 acres, primarily in northeast Washington (Fig. 29). This aerial survey signature is indicative of both larch needle blight (*Hypodermella laricis*) and larch casebearer (*Coleophora laricella*). Although larch casebearer damage was observed in early spring in Stevens County, ground checks indicated that larch needle blight was the primary cause of the damage. The casebearer/*Hypodermella* signature has not been recorded since 2013. Defoliation by larch needle cast disease (*Meria laricis*) was mapped on approximately 3,300 acres in 2017.

Glenn Kohler, Washington DNR

Figure 29. *Symptoms of larch needle blight in western larch.*

Gypsy Moth (*Lymantria dispar* Linnaeus) NON-NATIVE

In 2017, the Washington State Department of Agriculture (WSDA) deployed nearly 30,000 gypsy moth pheromone traps in Washington, including detection and delimiting traps for both European gypsy moth (EGM) and Asian gypsy moth (AGM). 117 EGM adults were trapped in 2017, the highest number in 20 years. WSDA was alerted to a reproducing population of EGM near Graham in Pierce County. With landowner cooperation, crews worked to remove vegetation and live gypsy moths (over 100 adult moths, dozens of egg masses (Fig. 30), and live pupae) from the area in an effort to slow the spread of the population. WSDA is proposing to conduct eradication projects with the bacterial insecticide *Bacillis thuringiensis* var. *kurstaki* (B.t.k) in the vicinities of Graham (Pierce County) and Silverdale (Kitsap County) in spring 2018 using aerial application. For more detail, go to: https://agr.wa.gov/PlantsInsects/InsectPests/GypsyMoth/

Karla Salp, Washington State Department of Agriculture, Bugwood.org

Figure 30. *Gypsy moth female laying egg mass.*

WSDA conducted a gypsy moth eradication project in spring 2016, treating more than 10,000 acres with B.t.k. Six of the sites were treated for AGM and one site (Seattle) was treated for an EGM introduction. Treatment areas were located in King, Pierce, Thurston and Clark counties. 2017 was the second year WSDA placed a high density of delimitation traps around treated areas to detect new adults. No moths were collected in the 2016 and 2017 delimitation traps. One more year of no catches will indicate those introductions were successfully eradicated.

Branch and Terminal Insects

Balsam Woolly Adelgid (*Adelges piceae* Ratzeburg) NON-NATIVE

Balsam woolly adelgid (BWA) is a non-native sucking insect that has caused defoliation and mortality to subalpine fir, Pacific silver fir, and grand fir in (Fig. 31). Most of the damage visible from the air is to subalpine fir in high elevation forests. In 2017, approximately 46,400 acres with damage was observed, similar to the 43,700 acres in 2016 and above the 10-year average of 36,000 acres (Fig. 32). BWA damage, primarily to subalpine fir and Pacific silver fir, was recorded at high elevations of the Blue Mountains, the Olympic Mountains, and in scattered areas near the crest of the Cascade Mountains and mountains of northeast Washington. There were approximately 20,000 acres with some host mortality attributed to BWA damage in 2017. Approximately 26,000 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.

Glenn Kohler, Washington DNR

Figure 31. *Stem deformities (gouting) in subalpine fir caused by balsam woolly adelgid infestation.*

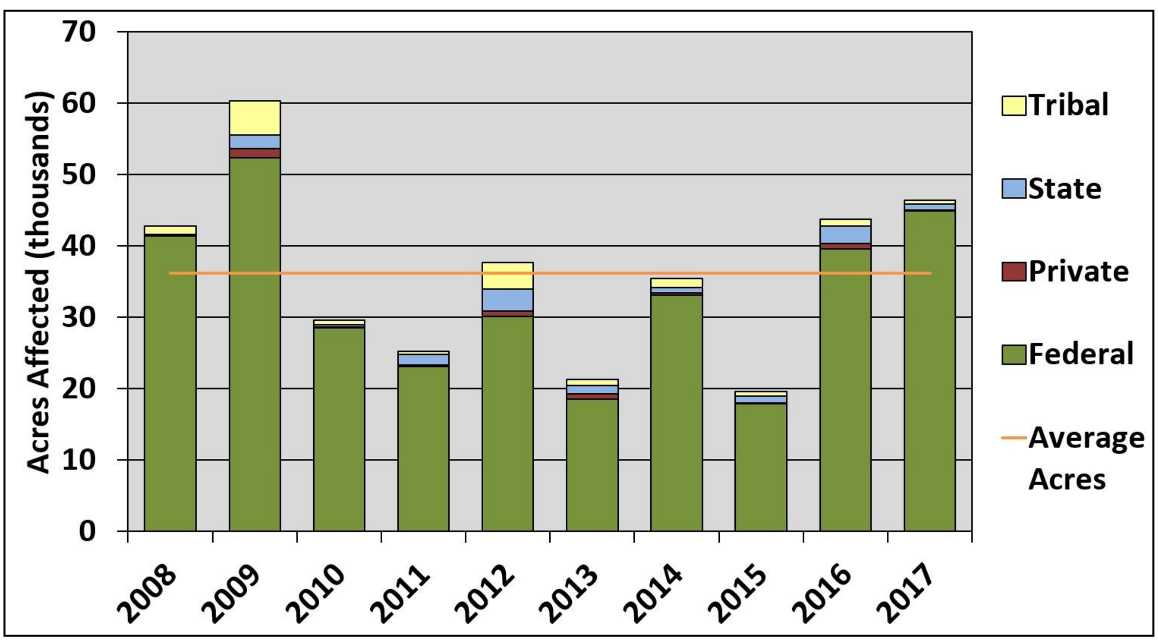


Figure 32. *Ten year trend for total acres affected by balsam woolly adelgid in Washington.*

Animals

Bear Damage / Root Disease

Figure 33. *Young conifer mortality from bear damage as seen from the air.*

Aerial survey records scattered, pole-sized, newly dead trees as 'bear damage' (Fig. 33). Based on ground checking observations, bear girdling and root disease are the primary causes of this type of damage. Drought stress, porcupines or mountain beavers may also play a role. Bears strip tree bark in spring. It takes more than one year for the tree to die and needles to become red (visible from the air). In drought years, trees may fade the same year they were injured. In years with wet and cool spring conditions, the berries that bears feed on mature later, so bears are more likely to feed on trees as an alternative. Also, above average spring precipitation may delay tree needles becoming red 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.

Approximately 81,200 acres with bear damage mortality were observed in 2017, similar to the 77,200 acres mapped in 2016 (Fig. 34). The ten year average of acres with bear damage in Washington is 206,000. The average number of trees per acre (TPA) killed was much higher in 2017 (2.57 TPA) than 2016 (1.70 TPA). The estimated total number of trees killed was approximately 209,000, significantly higher than the 131,000 trees killed in 2016.

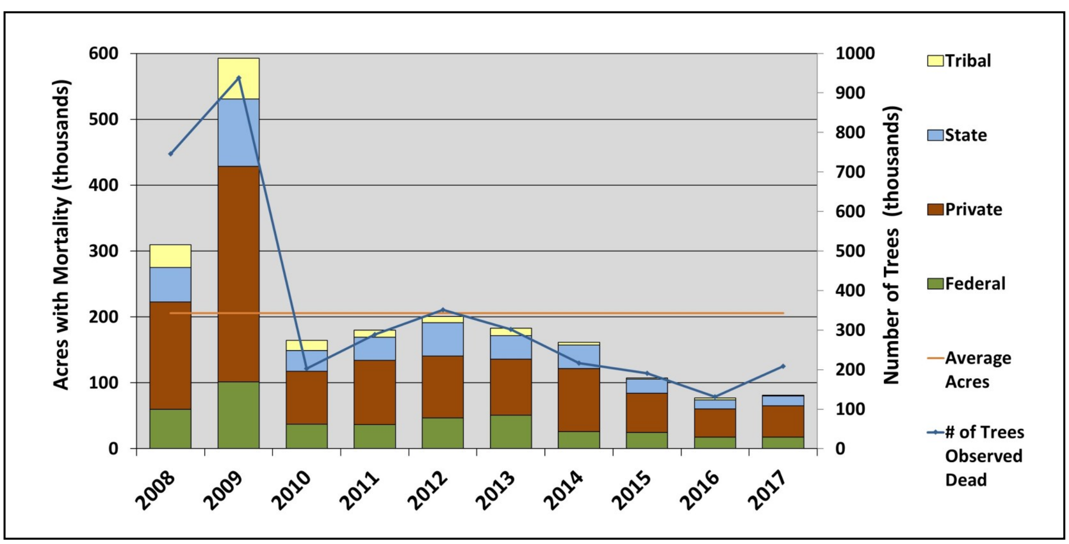


Figure 34. *Ten year trend for acres and number of trees affected by bear damage in Washington.*

Diseases

Foliar and Branch Diseases

Swiss Needle Cast on Douglas-fir (*Phaeocryptopus gaeumannii* (Rhode) Petrak)

The fungus that causes Swiss needle cast (SNC), *Phaeocryptopus gaeumannii* is found throughout the range of its only host, Douglas-fir. Swiss needle cast causes premature foliage loss and defoliation and can reduce growth of host trees, alter wood properties, and affect stand structure and development (Fig. 35). The disease is most damaging near the coast due to the fungi-favorable climatic (mild winters and wet, late springs) and topographic conditions. The Washington State Legislature is funding a special aerial survey for SNC in 2018. The aerial survey flight and on the ground disease incidence and severity assessments will occur in April and May, 2018.

Amy Ramsey, Washington DNR

Figure 35. *Douglas-fir trees with Swiss needle cast have black, fungal reproductive structures called pseudothecia growing in the stomata on the underside of the needles. While the pseudothecia are usually only visible with the aid of a magnification device, the underside of the foliage in the larger photo looks dirty due to the high level of infection.*

Bigleaf Maple Decline (BLMD) and Mortality

In 2010, reports of bigleaf maple (*Acer macrophyllum* Pursh) decline (BLMD) and mortality began to reach the WDNR from the general public, land owners, and forest land managers. This prompted an exploratory survey throughout the range of bigleaf maple in Washington, which revealed widespread decline. Symptoms of this decline include yellow flagging of large branches, small leaf size, partial or entire crown dieback, and mortality (Figs. 36-38).

No diseases or insects have been found in significant numbers or levels to indicate a causative agent. Samples submitted by WDNR to WSDA in 2016 and 2017 did not find any evidence of vascular damaging *Xylella fastidiosa* or *Phytoplasma asteris*, but two samples in the North Cascades were found positive for *Verticillium* species.

Amy Ramsey, Washington DNR

Figure 36. *A bigleaf maple tree showing symptoms of decline, including dead branches, small leaves and a thin crown.*

A project led by Jake Betzen at the University of Washington was initiated in 2017. He surveyed tenth-acre plots at a subset of previously sampled WDNR survey sites and randomized plots on public land, such as the USFS and National Park Service, in western Washington. In these plots, he recorded basic forest measurements, collected soil and leaf samples from healthy and declining bigleaf maple, and extracted tree cores from a subset of bigleaf maple and Douglas-fir. Betzen also collected weather, soil, and land use information from online databases. Initial results indicate substantial bigleaf maple decline throughout western Washington and a correlation between the severity of decline in bigleaf maple to road proximity.

Future research will involve an elemental analysis on the leaf and soil samples, and dendrochronological analysis on the tree cores. Betzen will attempt to statistically determine whether any of the possible biotic or abiotic factors are correlated with presence, extent and severity of BLMD, and determine the temporal and spatial record of the decline's spread and establishment. These data will hopefully indicate the presence or absence of a pathological agent and provide additional information regarding the cause of BLMD.

Amy Ramsey, Washington DNR

Figure 37. *One characteristic symptom of bigleaf maple decline includes a shrunken and waxy leaves, as pictured on the right.*

Beth Willhite, an entomologist with the USFS, has also been studying whether a leafhopper is carrying pathogens, such as a virus, and infecting the trees. There have been no clear associations made among leaf hoppers, pathogens and BLMD.

Amy Ramsey, Washington DNR

Figure 38. *Another symptom of bigleaf maple decline may include yellow and brown tipped leaves during the growing season.*

Sudden Oak Death

Sudden Oak Death *(Phytophthora ramorum* Werres et al.) NON-NATIVE

Zack Heath, USDA Forest Service

Figure 39. Phytophthora ramorum *caused tanoak tree mortality (red and grey trees) near Carmel, CA.*

Amy Ramsey, Washington DNR

Figure 40. *Native rhododendrons , a host of* Phytophthora ramorum*, in western Washington native forests.*

Phytophthora ramorum (*Pr*), an exotic plant pathogen, is the causal agent of Sudden Oak Death (SOD), ramorum leaf blight and ramorum dieback and has caused extensive mortality of tanoak and several other oak species in southern Oregon and California (Fig. 39). The pathogen can move aerially through landscapes with wind and wind-driven rain and can also be moved long distances through transported infested nursery stock. Western Washington is at risk for *Pr* caused disease and *Pr* spread due to hosts in the natural environment (Fig. 40), suitable climatic conditions (moist weather and mild temperatures), the presence of plant nurseries with *Pr* infected host stock and water runoff associated with contaminated nurseries. To date, the pathogen has only been detected in locations that are either at or near plant nurseries, in one privately owned botanical garden and not in general forests in western Washington. Our native Garry or Oregon white oaks are not considered susceptible and have not been found infected. Furthermore, we have not observed any damage caused by this pathogen similar to those occurring in southern Oregon or California in our forests.

METHODS AND RESULTS

With funding provided by the USFS, the National *Phytopthora ramorum* Early Detection Survey of Forests has been ongoing since 2003 (Fig. 41). In 2017, ten Washington waterways in seven counties (Clark, Cowlitz, King, Kitsap, Lewis, Mason and Thurston) were surveyed for the pathogen using a rhododendron leaf filled baiting bag method. Two waterways in King County were found positive for *Pr*. The pathogen was detected for the first time in Issaquah Creek at a site downstream from a now-closed nursery that previously contained positive *Pr* nursery stock.

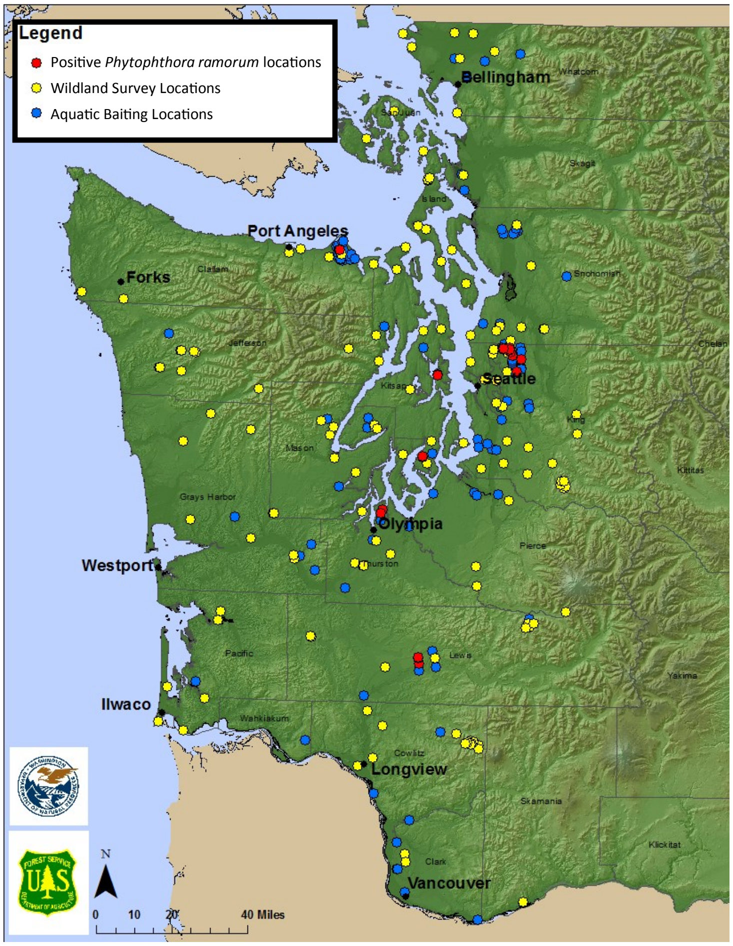


Figure 41. *Washington Department of Natural Resources* Phytophthora ramorum *monitoring, detection and survey sites, 2003-2017. Map by: Amy Ramsey Washington DNR.*

There are no indications that the pathogen is leaving the waterway as all vegetation samples collected in the woodlands bordering the waterway were negative for *Pr*. *Phytophthora ramorum* has been detected at the second site, the Sammamish Slough, since 2007.

THE BLOEDEL RESERVE PROJECT UPDATE

Provided by Paul Manzanares, WA State Dept. of Agriculture

For the last 3 years, the Washington State Department of Agriculture's Plant Pathology Laboratory has been working in conjunction with The Bloedel Reserve on Bainbridge Island regarding their *Pr* infestations. In 2017, four surveys were conducted in the reserve with nearly 4000 samples gathered. Samples were obtained through baiting of the reserve's watersheds and collecting leaves in both wild and cultivated areas of the reserve. *Pr* was not detected in 2017 because of the hard work and due diligence of both the WSDA and The Bloedel Reserve.

The Bloedel Reserve offers a unique horticultural environment. Their gardens are well established with mature cultivars from around the world growing within and next to native Washington flora. The introduction of nursery stock and the thousands of visitors to the reserve every year creates an environment for further contamination of *Pr*. The continual surveying of the WSDA has supported Bloedel and its staff in the eradication of this disease through culling of infected plants, intensive steam treatment of soil in infected areas, and biological soil treatments of *Trichoderma*. The Bloedel Reserve's success in the mitigation and removal of this pathogen is a fantastic example of what can be accomplished with cooperation, hard work and dedication.

ADDITIONAL RESOURCES

For more information about *Phytophthora ramorum* and Sudden Oak Death, please visit the California Oak Mortality Task Force website at: http://www.suddenoakdeath.org/.

Other Non-Native *Phytophthora* species

Phytophthora alni **Brasier & S.A. Kirk NON-NATIVE**
Phytophthora austrocedrae **Gresl. & E.M. Hansen NON-NATIVE**
Phytophthora quercina **T. Jung NON-NATIVE**

Through funding from the USDA APHIS and a cooperative agreement between WDNR and WSDA, detection efforts for fungus-like, invasive, pathogenic *Phytophthora* species: *P. alni*, *P. austrocedrae* and *P. quercina*, were implemented in western Washington waterways in the spring and fall of 2017. Rhododendron leaf filled baiting bags were placed in targeted waterways for one to two weeks, then submitted to the WSDA Plant Pathology lab for analysis. All submitted samples have been negative for *P. alni*, *P. austrocedrae* and *P. quercina*.

Phytophthora alni causes lethal root and collar rot in alders, with greatest impacts observed in riparian ecosystems (Figs. 42-44). It was first discovered in England and has since been identified in many other European countries, causing greater than 15% mortality in surveyed areas. Hosts in Europe include common alder (*Alnus glutinosa*), grey alder (*A. incana*), Italian alder (*A. cordata*) and green alder (*A. viridis*), each with varying levels of susceptibility. *Phytophthora alni* ssp. *uniformis* has been identified in Alaska and Oregon in wildland streams, but only in soils and has not been found causing disease in alders in Alaska. Small necrotic lesions caused by the pathogen have been reported on red alder (*Alnus rubra*) roots in Oregon. Red alder is a native Washington tree and we have been monitoring for *P. alni* with no positive findings to date.

Everett Hansen, Oregon State University

Figure 42. Phytophthora alni *caused dieback in alder in France.*

Forestryimages.org

Figure 43. *Bleeding spot cankers caused by* Phytophthora alni *on European black alder (Alnus glutinosa).*

Thomas Jung, Bugwood.org

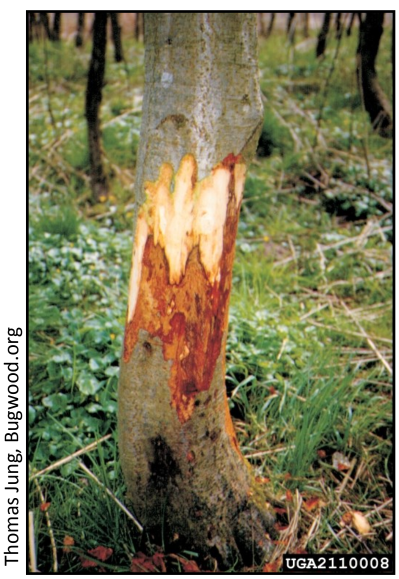


Figure 44. *Grey alder (*Alnus incana*) with collar rot and staining caused by* Phytophthora alni.

Phytophthora austrocedrae causes dieback and mortality of common juniper (*Juniperus communis*) in northern Great Britain by attacking the roots and stem bases of the host. Other hosts of the pathogen include Chilean juniper (*Austrocedrus chilensis)*, Lawson cypress (*Chamaecyparis lawsoniana*), Nootka cypress (*Chamaecyparis nootkatensis*) and creeping juniper (*Juniperus horizontalis*) (Figs. 45-46). The pathogen is likely spreading via human-assisted pathways. Washington is at risk for the establishment of *P. austrocedrae* due to the presence of known hosts and the cool temperatures (50° to 68.5° F) required for growth and reproduction of the pathogen.

Everett Hansen, Oregon State University

Figure 45. *Dead and dying trees caused by* Phytophthora austrocedrae *along a river.*

Everett Hansen, Oregon State University

Figure 46. Phytophthora austrocedrae *caused necrotic lesion in phloem of host tree.*

Phytophthora quercina has been associated with declining European oak stands and has been found infecting oak species in multiple European countries, as well as Turkey. Tree mortality is often gradual and may be associated with other site factors such as drought, flooding, defoliation and tree species composition (Fig. 47). Other damage symptoms in infected hosts may be similar to other pathogens causing decline of oak species, including leaf clusters, reduced growth, branch and crown dieback, yellowing leaves, bleeding infections at the base of the tree, among others. Hosts of the *P. quercina* include multiple oak species and may be moved around via contaminated soil, water and nursery stock. Risk assessments have suggested that the southeast US likely has the greatest risk for damage from this pathogen due to host density, climate and introduction pathways. We are monitoring for *P. quercina* in Washington due to the presence of native oak species.

Forestryimages.org

Figure 47. Phytophthora quercina *caused dieback and decline in oak tree.*

White Pine Blister Rust (*Cronartium ribicola* Fisch.) NON-NATIVE

Amy Ramsey, Washington DNR

Figure 48. Whitebark pine tree with topkill caused by the disease white pine blister rust.

Western white pine (*Pinus monticola*, WWP) and whitebark pine (*Pinus albicaulis*, WBP) are native conifer species in western North America and are both susceptible to the introduced, non-native fungal pathogen *Cronartium ribicola*, the causative agent of white pine blister rust (WPBR). The impacts of WPBR have reduced the incidence of WWP and WBP in natural ecosystems, contributing to reluctance in using WWP in reforestation activities and the proposal for listing WBP, a high-elevation growing species, under the Endangered Species Act (Fig. 48). Fortunately there is some genetic variation in resistance to WPBR in both WWP and WBP and there are regional programs focusing on testing and developing increased levels of WPBR resistant seed stock. Resistance can vary widely among families and field testing is essential to validate resistance and to monitor the efficacy of blister rust resistance over time in a changing climate and potential evolution in virulence of the pathogen. Field trials can serve to provide information on the adaptive capacity of the species to changing environmental conditions and provide guidance for seed transfer.

In 2017, in collaboration with the USFS Dorena Genetic Resource Center (Dorena GRC), the USFS Colville National Forest, the Colville Confederated Tribes and Bureau of Indian Affairs, and the British Columbia Ministry of Forests, Lands and Natural Resource Operations, five trial sites were established to evaluate WBP seedlots and their resistance to WPBR (four trials in eastern WA, one trial in western OR, Figs. 49-51). A subset of the plantings were also established for the genetic conservation of selected WBP families and potentially future seed orchards.

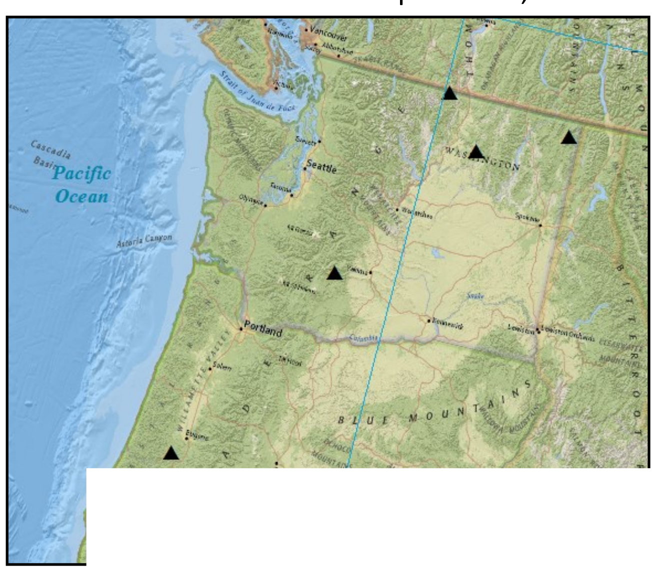


Figure 49. *Locations of whitebark pine white pine blister rust resistance trials installed in eastern Washington (4 sites) and western Oregon (1 site) in fall 2015 and 2017, shown as black triangles.* *Map by: Amy Ramsey Washington DNR.*

Richard Sniezko, USDA Forest Service

Figure 50. *A whitebark pine trial site planted in 2015 at Tyrrell Seed Orchard, OR.*

Dan Omdal, Washington DNR

Figure 51. *A whitebark pine trial site planted in 2015 in an area burned during the Newby Creek fire, Good Enough Peak, WA.*

PROJECT OBJECTIVES INCLUDE:

1) Use WBP resistant seed stock to establish the most advanced trial series for WPBR resistance evaluation.
2) Establish field sites with WBP seedlings from different families that can be used for potential seed orchards and clone banks.
3) Provide conservation of the species in multiple locations.
4) Assess impacts of abiotic and biotic agents on diverse WBP seed sources.
5) Examine growth, general vigor and reproductive status of WBP seedlots from diverse geographic areas to help evaluate seed movement potential in a changing climate.
6) Link these trials with related trials planted in British Columbia in 2015/2016.
7) Provide updates to landowners on the levels of rust incidence and field resistance currently available.
8) Use trials for fieldtrips, conservation education, and potential student projects.

Amy Ramsey, Washington DNR

Figure 52. *Western white pine (WWP) white pine blister rust resistance trial site with red, dead, and chlorotic WWP in the foreground.*

The WDNR continues to have an active role in establishing, assessing and maintaining WPBR resistant WWP trials and operational assessments in an effort to provide the most current information regarding the disease and species to forest managers across the state (Fig. 52). Western white pine can be a useful reforestation and restoration species due to its ability to grow on a wide variety of sites and its tolerance to laminated root rot, a common root disease in Washington.

Root Diseases

Figure 53. *A Douglas-fir forest with laminated root rot killed trees.*

Several important root diseases affect the trees in Washington forests, including Armillaria root disease (caused by species of *Armillaria* fungi), laminated root rot (caused by the fungi *Phellinus sulphurascens* and *Phellinus weirii*) and Annosus root disease (caused by the fungi *Heterobasidion irregulare* and *H. occidentale*). All root diseases can have significant impacts on forest dynamics, including tree growth, tree mortality, species diversity and stand structure (Fig. 53).

LAMINATED ROOT ROT AND COMMERCIAL THINNING

Figure 54. (Left). *A recent commercially thinned Douglas-fir forest with laminated root rot caused mortality and thinning crowns.*

In March 2017, Forest Pathologists from WDNR assessed the extent of root disease damage across two sites that had recently been commercially thinned in western Washington. The sites were primarily composed of 35-40 year old Douglas-fir with components of salal, swordfern and Oregon grape in the understory. All trees were surveyed for tree health in twenty 1/10-acre plots. All dead conifer trees and stumps were examined for the presence of root diseases (Fig. 54).

Root disease, caused by the fungi *Phellinus sulphurascens* (laminated root rot (LRR)), *Armillaria* species (Armillaria root disease) and *Heterobasidion occidentale* (Heterobasidion root and butt rot), were found causing damage on 95% of the plots surveyed. The primary damage causing root disease was LRR, found on 83% and 63% of each site. All root diseases were found scattered throughout the units and not in discrete pockets.

Commercial thinning exacerbated the root disease damage that was already present. In the future, thinning should be avoided in infested areas. A regeneration harvest may be more appropriate management strategy on sites like this, focusing attention on replanting with species less susceptible to LRR.

Figure 55. *A Douglas-fir forest with trees killed by Armillaria root disease.*

Figure 56. *A Douglas-fir forest with Armillaria root disease killed trees.*

ARMILLARIA ROOT DISEASE AND DOUGLAS-FIR

In December 2017, WDNR assessed the extent of root disease damage in an approximately 70 year old Douglas-fir stand in western Washington. The site was on a south-facing slope, where sword fern, salal and Oregon grape were in the understory. Transects were surveyed for tree mortality and associated causal agents. All dead conifer trees, including those that recently died and old snags, were examined for the presence of mortality causing bark beetles and root disease (Fig. 55).

The primary mortality agent was Armillaria root disease (*Armillaria* species), with *Phellinus sulphurascens* (the cause of LRR), found in only one pocket. Most of the root disease was found in distinct pockets, but there were also areas with scattered mortality. Based on the survey, at least 25% of the stand was infected with root disease (Fig. 56).

Due to the age of the forest, the basal area and density, the dry soils and south facing aspect, the exceptionally dry and hot temperatures in 2015 and 2017 likely contributed to the stress of the recently killed and currently symptomatic trees. These increased stresses often contribute to the reduced defensive capability of the host to the disease causing pathogen, often resulting in increased damage and mortality in trees.

If a regeneration harvest and replant were to occur in the future, planting a diverse mix of site appropriate species post-harvest would be the best course of action. These species may include Douglas-fir, western hemlock, and western white pine. If thinning is being considered, it should be noted that thinning in root disease infested areas may contribute to higher than expected levels of mortality in the residual stand.

Data and Services

Every year, all forested acres in Washington are surveyed from the air to record recent tree damage. This aerial survey is made possible by the cooperation of the WDNR and the USFS. It is very cost effective for the amount 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 2017 are available for download as PDF files at:
www.fs.usda.gov/goto/r6/fhp/ads/maps

Click on the year of interest under "Aerial Detection Survey Quad Maps" (Fig. 57). Scroll down to view an interactive map of all the available quads from Oregon and Washington. Simply click the quad map you want and it will download the PDF. Polygons are colored to reflect damage type and are labelled with a damage agent code. The code is followed by a modifier indicating number of trees affected, trees per acre affected, or intensity of damage (L-light, M-moderate, H-Heavy). Damage codes are defined in a legend in the lower left side of each quad map (Fig. 58).

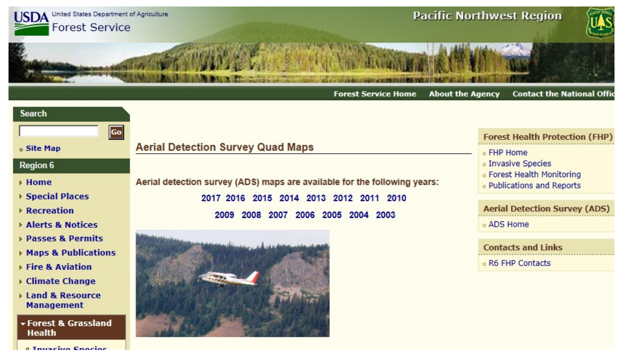


Figure 57. *Aerial survey maps and data on USFS Region 6 Forest Health Protection website.*

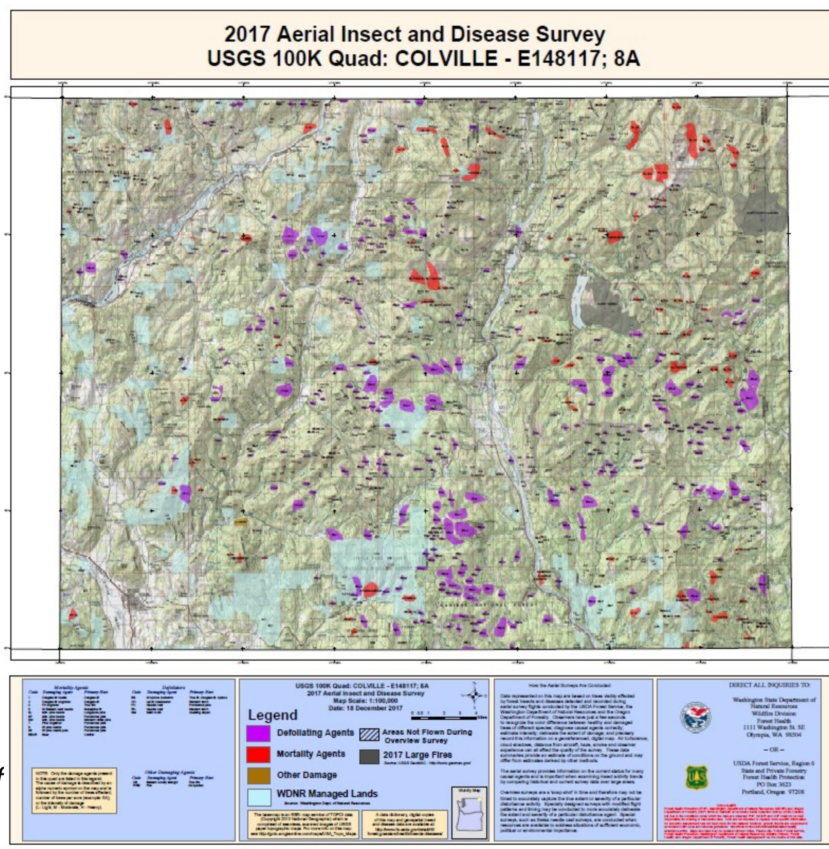


Figure 58. *Example PDF map of the Colville quad for 2017.*

Interactive Map Tools

2011 to 2017 annual aerial survey data and the 15-year cumulative mortality data product are available from Washington DNR's interactive, web-based mapping site: "Fire Prevention and Fuels Management Mapping" at:
https://fmanfire.dnr.wa.gov/default.aspx. On the left side of the page, click on "Forest Health", select "Annual Aerial Survey Data" and the year of interest, then check boxes for type of damage to be displayed. Click on polygons to display agent and intensity. Various basemaps and background layers can be added. Zoom to an area of interest and click the printer icon in the upper right to create a pdf or image file of your map.

Customized electronic maps (PDF, JPG, etc.) of draft data can be created with a variety of background layers at: http://usfs.maps.arcgis.com/apps/webappviewer/index.html?id=87d6cf9c2e1a45408ef01a357b84c811
Zoom in to the area of interest, click the printer icon, select the type of output you need, click 'print' and it will generate a file. Output PDFs are georeferenced for use in PDF viewer apps on mobile devices.

GIS Data Available for Download

Washington DNR also maintains downloadable GIS datasets, including aerial survey data for Washington State from 1980 to 2017, known as "Forest Health Aerial Survey 1980-2017" at:
http://www.dnr.wa.gov/GIS, under "Forest Disturbance."

Forest Health Websites

Washington Forest Health Highlights reports are published annually and include the latest information on exotic pest problems, insect and disease outbreaks and recent forest damage trends for Washington. Recent annual reports, WDNR research, and other forest health information are available at: http://www.dnr.wa.gov/ForestHealth

Historic annual highlights reports for Alaska, California, Oregon, Washington, Hawaii and the Pacific Islands are available at: www.fs.usda.gov/goto/r6/fhp/highlights

Major insect and disease identification and management information, illustrations, and graphical trend analysis of Pacific Northwest forest health issues are available at:
www.fs.usda.gov/goto/r6/fhp

Forest Health Contacts

If you have questions about forest insect and disease activity in Washington, please contact one of these regional or field offices:

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