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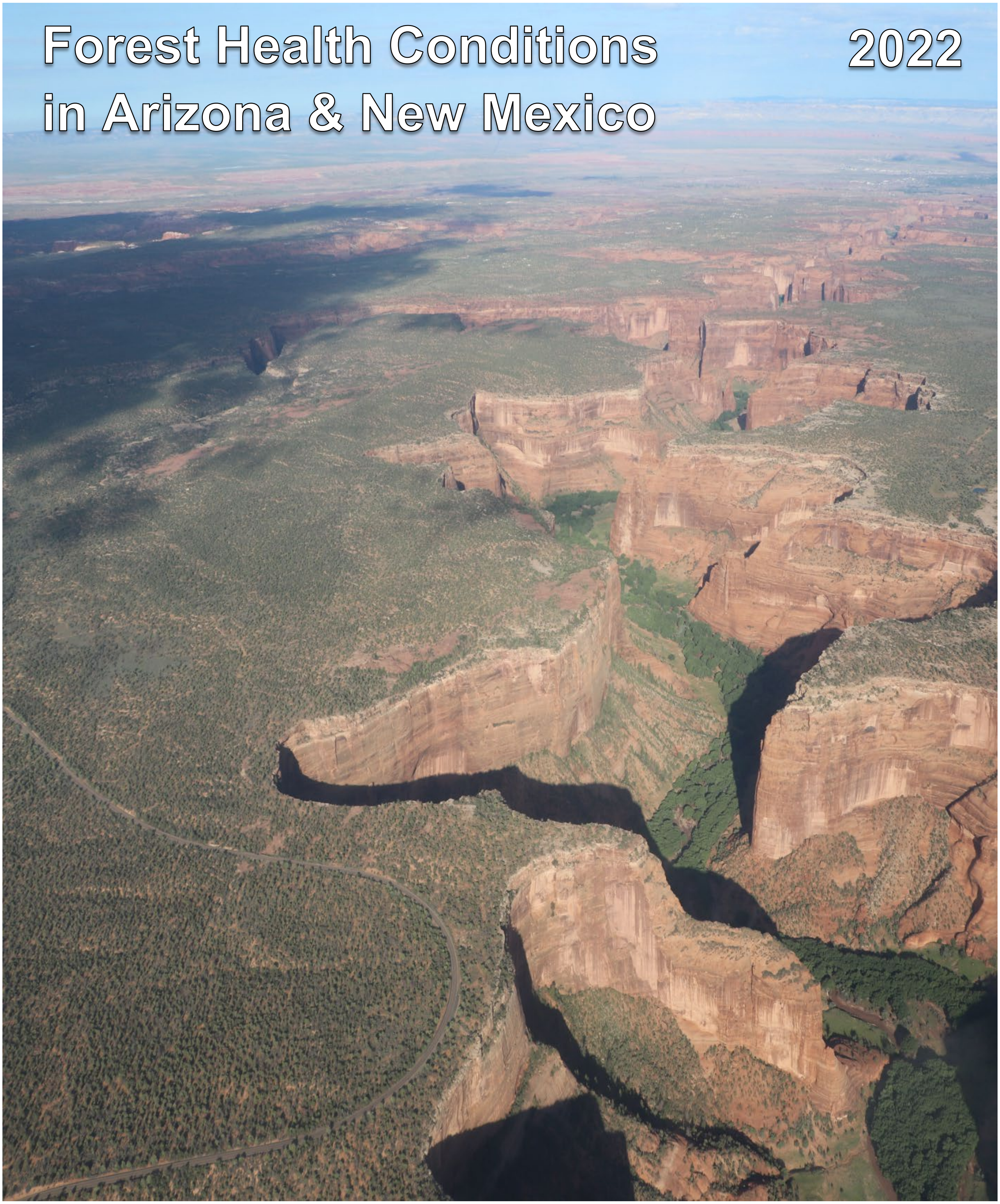
Forest Health Conditions in Arizona & New Mexico 2022



Cover photo: Pinyon pine mortality and juniper dieback above Canyon de Chelly NM, AZ. USDA Forest Service photo.

Forest Health Conditions in Arizona and New Mexico - 2022

Southwestern Region
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Contents

List of Figures

List of Tables

Weather Conditions in Brief

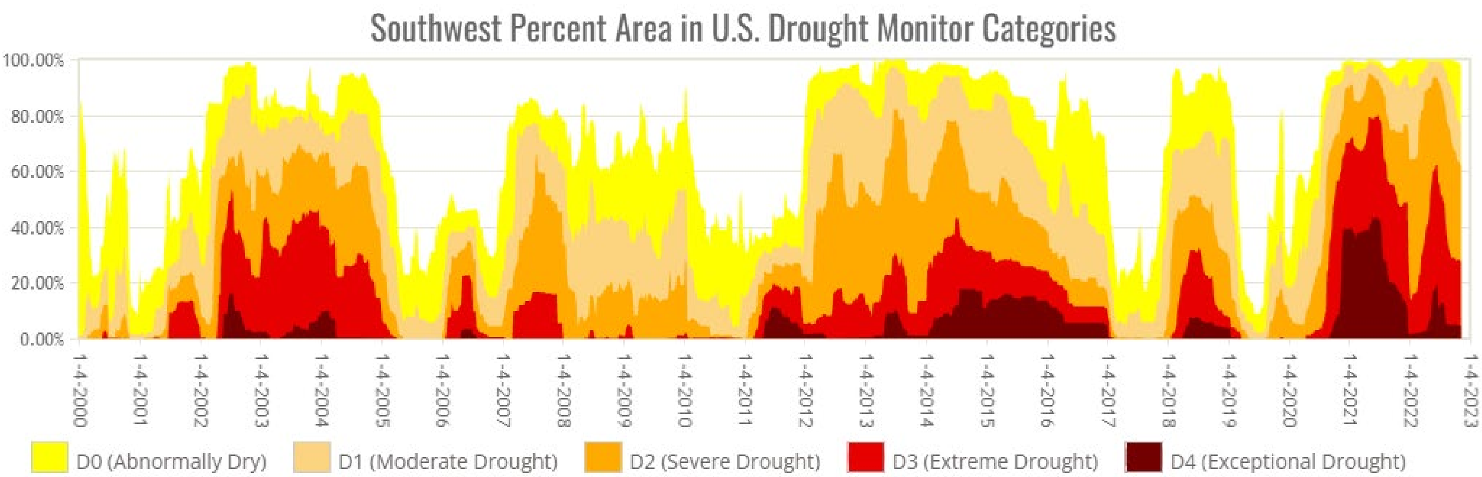


Figure 1. Percent of the Southwestern U.S. in various drought monitor categories from 2000-2022 (Source: U.S. Drought Monitor, https://droughtmonitor.unl.edu/DmData/TimeSeries.aspx).

Drought

Over the last 22 years, the Southwestern US has experienced multiple extended drought periods with recovery periods that are relatively short (Figure 1). In the current drought event that started in 2019, exceptional drought has affected more than 40% of the southwestern US. The area impacted by exceptional and extreme drought decreased between 2021 and 2022 due to increased monsoonal moisture. However, this small increase in precipitation was not enough to ease chronic drought stress, particularly in woodlands in the northern part of the region and across conifer forests region wide. It will require multiple years of adequate precipitation to alleviate impacts from chronic drought stress in forests and woodlands of Arizona and New Mexico.

Evidence of prolonged drought stress was observed in all tree species across the Southwest, especially in ponderosa pine, juniper, deciduous oaks, and other woodland species. At the landscape level, drought stress occurred most heavily across the Mogollon Rim and in northern Arizona and throughout central and northern New Mexico. Abiotic stressors, such as drought and heat, can increase the susceptibility of trees to insects and diseases that do not normally affect healthy, vigorous trees.

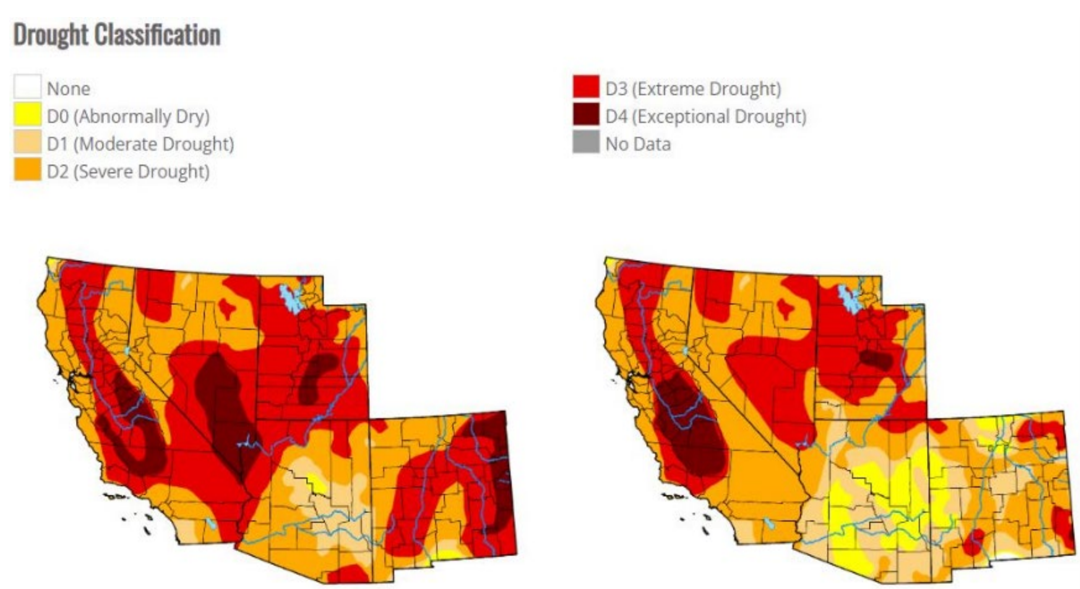


Figure 2. U.S. Drought Monitor comparison map of the Southwestern United States between June 28 (left) and August 30, 2022 (right). Drought conditions improved in both Arizona and New Mexico (Source: U.S. Drought Monitor, https://droughtmonitor.unl.edu).

Drought Conditions at the Start and End of the Survey Season

The Southwestern Region experienced various drought intensities according to the United States Drought Monitor entering 2022 and these conditions persisted throughout the survey season (Figure 2). In fact, the region continued to experience higher than normal temperatures and the drought status worsened to exceptional (D4) in some areas by the end of June. A productive monsoon season brought significant amounts of precipitation into the Southwestern Region and by August much of Arizona and New Mexico was no longer in extreme or exceptional drought status. Despite the active monsoon, tree mortality continued into the late summer and fall.

Warming Temperatures

Higher than normal temperatures compounded drought effects across all forest types. Approximately 75% of Arizona and New Mexico experienced above normal and much above normal temperatures during the months of July thru October. Higher temperatures cause increased atmospheric evaporative demand which has a serious effect on vegetation moisture retention by accelerating plant transpiration rates.

Climate projections predict increases in temperature and drought frequency and intensity in the Southwest - potentially leading to fundamental and drastic ecosystem shifts. Data from the USFS National Insect and Disease Risk Map highlight the risk of substantial tree mortality from insects and diseases through 2027. Continued regionwide monitoring of forest health is crucial for effective forest resource management in a changing climate.

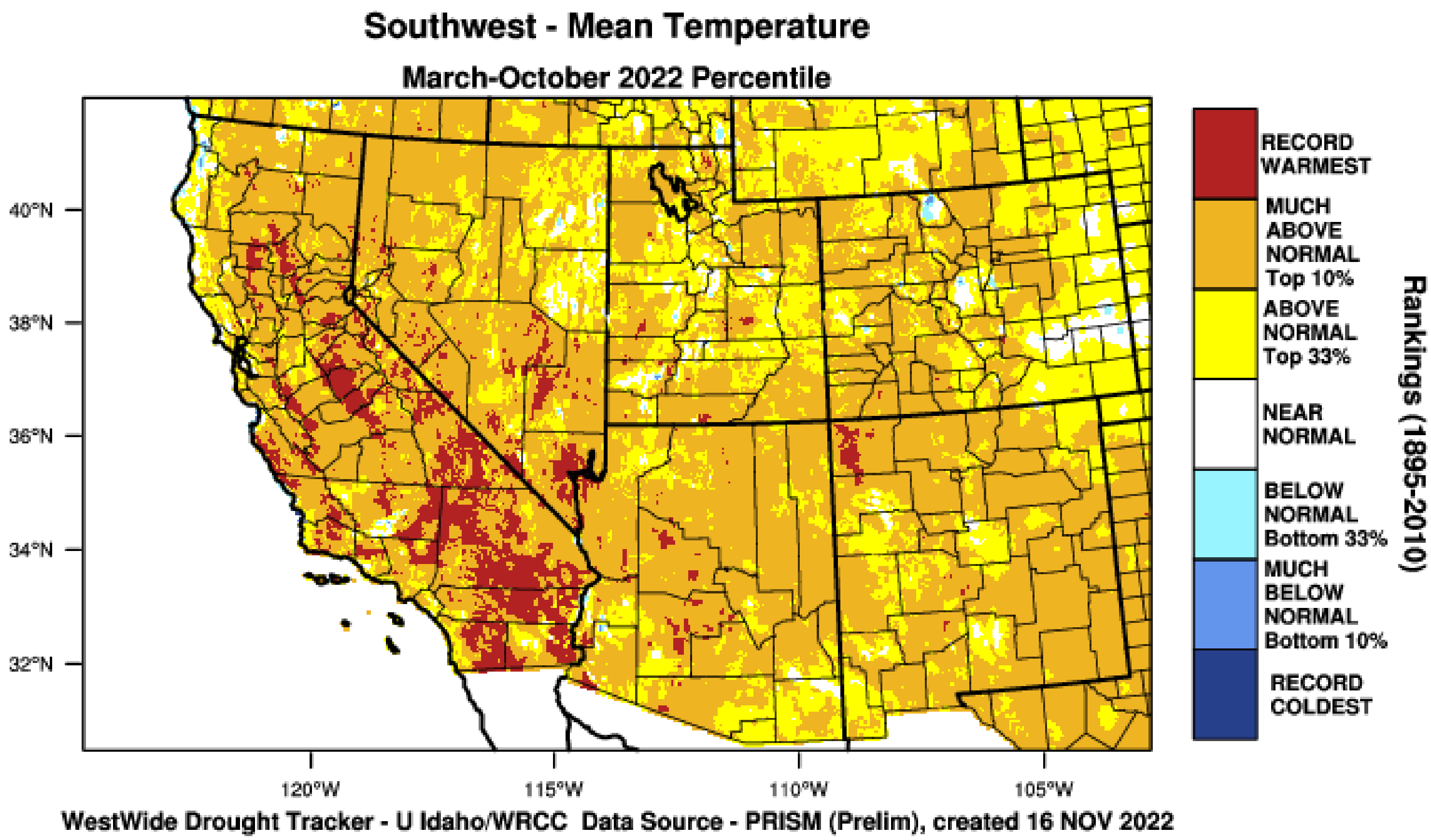


Figure 3. Mean temperature rankings for the Southwestern U.S., July-October 2022 (Source: WestWide Drought Tracker; U Idaho/WRCC, https://wrcc.dri.edu/my/wwdt).

Regional Forest Insect and Disease Summary

Aerial Survey Summary

In 2022, aerial detection surveys (ADS) covered approximately 22 million acres of the Southwestern Region. Aerial surveys primarily covered national forest land (55% of area surveyed), followed by tribal (24%), state and private (17%), and other federal lands (4%) (Table 1, Figure 4, 11.2 million acres surveyed). An ArcGIS Online Story Map summarizing the 2022 ADS results and discussing the major forest health issues observed throughout Arizona and New Mexico during 2022 can be accessed at https://storymaps.arcgis.com/stories/7e91536902d54367b8b952607126ad74.

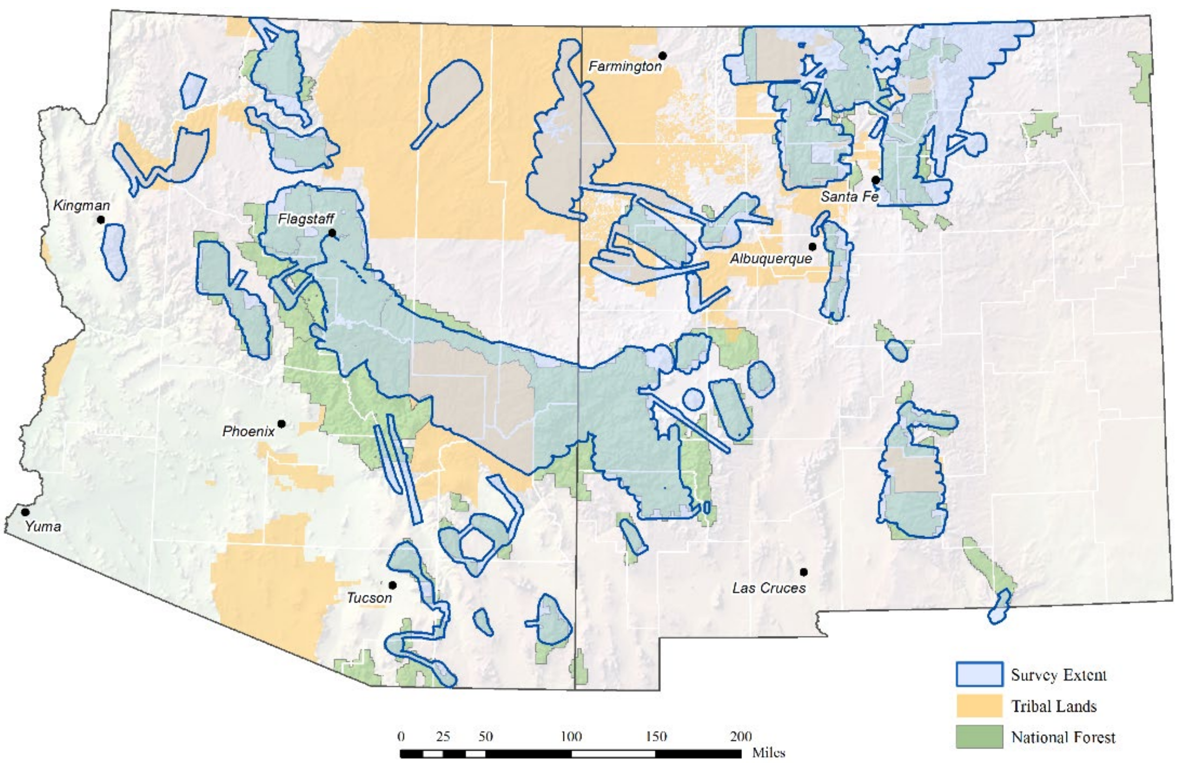


Figure 4. Areas surveyed during 2022 Aerial Detection Survey flights.

Table 1. Aerial Detection Survey acres flown in 2022 in the Southwestern Region.[1]

Land ownership	State	Forested	Woodland	Total
National Forest Lands	AZ	3,139,100	2,745,400	5,884,500
Bureau of Land Management	AZ	22,800	131,400	154,200
Department of Defense	AZ	29,200	21,600	50,800
National Park Service	AZ	132,400	179,100	311,500
Bureau of Reclamation	AZ	100		100
Tribal	AZ	1,385,400	2,265,500	3,650,900
State and Private	AZ	226,800	384,500	611,300
Arizona Total		**4,935,700**	**5,727,500**	**10,663,200**
National Forest Lands	NM	4,047,000	2,062,300	6,109,200
Bureau of Land Management	NM	54,300	258,800	313,100
Bureau of Reclamation	NM	1,600		1,600
Department of Defense	NM		800	800
Department of Energy	NM	3,800	5,900	9,700
National Park Service	NM	87,200	19,600	106,800
Tribal	NM	934,100	679,100	1,613,300
U.S. Fish & Wildlife Service	NM	100	300	400
State and Private	NM	1,866,800	1,213,200	3,080,000
New Mexico Total		**6,994,900**	**4,239,900**	**11,234,800**

[1]Values rounded to the nearest 100; sum of individual values may differ from totals due to rounding, blank cells indicate <50 acres surveyed.

Bark Beetle Summary

Tree mortality attributed to bark beetles was mapped on 752,360 acres in 2022, a slight decrease from 772,940 acres in 2021. Regionwide, pinyon ips contributed to the most acres with mortality of any bark beetle. Acres with pinyon mortality increased across the region from 135,780 in 2021 to 355,900 in 2022. The bark beetle-related mortality reported by ADS was likely due to the continuing drought conditions from the start of 2021 through June 2022.

In 2022, Arizona had 179,450 acres with bark beetle-related ponderosa pine mortality (Table 2) down from 427,010 acres in 2021. For the second year in a row, ponderosa pine bark beetles were the most prevalent mortality agent mapped in Arizona. The Coconino and Kaibab National Forests (NF) saw the largest areas with ponderosa pine mortality, with acres affected decreasing on both the Coconino NF from 165,660 acres in 2021 to 67,020 acres in 2022 and from 59,180 acres in 2021 to 39,520 acres in 2022 on the Kaibab NF. The Coconino and Kaibab NFs accounted for 59% of acres mapped with ponderosa mortality in Arizona (Figure 5). Pinyon mortality increased overall throughout the state to 167,680 acres in 2022, more than double the 68,940 acres recorded in 2021. The majority (75%) of pinyon mortality in Arizona was mapped on the Kaibab NF and the Navajo Nation tribal lands, where severe drought conditions persisted. On the Kaibab NF, the number of acres with pinyon mortality doubled from 32,380 in 2021 to 65,150 in 2022. The Navajo Nation tribal lands had a substantial increase of pinyon mortality with 61,040 acres in 2022, nearly eight times the acres recorded in 2021.

New Mexico had 188,220 acres with pinyon ips mortality in 2022 (Table 2), constituting most of the bark beetle-related mortality in New Mexico, up nearly threefold from the 66,830 acres mapped in 2021. The majority of pinyon mortality was observed on tribal lands across New Mexico, which accounted for 38% of total acres mapped. This was followed by state and private land accounting for 35% of the pinyon acres with mortality. Spruce beetle activity decreased in the region, with most of the activity occurring in New Mexico. Acres with spruce beetle-related mortality decreased in Arizona from 530 acres with mortality in 2021 to 330 acres in 2022.

Figure 5. Bark beetle-caused ponderosa pine mortality on the Coconino NF, Arizona. USDA Forest Service photo.

New Mexico likewise observed a decrease with 34,400 acres with mortality in 2021 falling to 24,660 acres in 2022. There was an increase observed on the Carson NF from 14,740 acres with mortality in 2021 to 16,070 acres in 2022. Regionwide, spruce beetle was primarily mapped in New Mexico (53% of total in region) on the Carson (64%) and Santa Fe (33%) NFs. Ponderosa pine acres with mortality mapped in New Mexico increased to 130,710 acres in 2022 from 116,080 acres in 2021 (Table 2). Most of the ponderosa mortality was observed on the Gila NF, which accounted for 64% of total mapped ponderosa mortality in the state.

Figure 6. Bark beetle-caused pinyon mortality on private land near the Datil Mountains, Cibola NF, New Mexico. USDA Forest Service photo.

Table 2. Bark beetle[1] incidence by ownership (acres) from aerial detection surveys in 2022 in Arizona and New Mexico[2].

Owner[3]	Ponderosa pine bark beetles[4]	Pinyon ips	Douglas-fir beetle	Fir engraver	Spruce beetle	Western balsam bark beetle
Apache-Sitgreaves National Forest	14,660	1,610	50	2,030	20	90
Coconino National Forest	67,020	1,630	330	6,230	30	190
Coronado National Forest	1,790	630	110	770		30
Kaibab National Forest	39,520	65,150	980	17,290	250	3,530
Prescott National Forest	6,460	1,170	< 5	490		
Tonto National Forest	12,400	2,010	70	1,760		10
Bureau of Land Management	2,330	2,630		20		
Department of Defense	760	20		< 5		
Canyon De Chelly National Monument	< 5	4,340				
Chiricahua National Monument	< 5					
Grand Canyon National Park	9,330	5,650	220	7,820	< 5	2,610
Lake Mead National Recreation Area		< 5				
Saguaro National Monument	100			60		
Walnut Canyon National Monument	< 5					
Havasupai Tribal		5,250				
Hopi Tribal		5,370				
Hopi Trust Land	60					
Hualapai Tribal	1,140	1,020				
Navajo Nation	6,400	61,040	540			480
San Carlos Apache	3,790	90		70		
White Mtn Apache	9,310	1,740	120	6,200	20	340
Other Tribal	540					
State & Private	3,830	8,330	< 5	200		
Arizona Total	**179,450**	**167,680**	**2,430**	**42,930**	**330**	**7,280**
Carson National Forest	850	3,940	4,410	900	16,070	< 5
Cibola National Forest	13,650	20,990	1,700	1,830		10
Gila National Forest	83,150	6,480	1,690	180		
Lincoln National Forest	5,460	1,460	230	410		
Santa Fe National Forest	4,320	3,230	11,930	2,460	8,320	20
Bureau of Land Management	1,960	15,200	420	100		
Department of Energy	< 5	< 5				
Bandelier National Monument	< 5		< 5			
El Malpais National Monument	460	10				
El Morro National Monument	< 5	10				
Pecos National Historical Park	< 5					
Valles Caldera National Preserve	290		70	30	< 5	
Acoma Pueblo	220	1,100				
Isleta Pueblo	260	< 5	90			
Jemez Pueblo	20	240	< 5			
Jicarilla Apache Tribal	20	800	190	< 5	< 5	< 5
Laguna Pueblo	580	< 5				
Mescalero Apache Tribal	3,970	10	20	50	< 5	50
Navajo Nation	1,630	35,830	560		50	470
Picuris Pueblo	< 5		< 5			
Ramah Tribal		9,990				
Santa Clara Pueblo	50	< 5	< 5		< 5	
Taos Pueblo	< 5	< 5	1,580	20	< 5	
Zia Pueblo	190		< 5			
Zuni Pueblo	1,110	23,280	< 5			
Other Tribal		70				
Cochiti Pueblo			< 5			
State & Private	12,510	65,580	2,380	870	220	10
New Mexico Total	**130,710**	**188,220**	**25,260**	**6,850**	**24,660**	**560**
Grand Total	**310,160**	**355,900**	**27,680**	**49,780**	**24,980**	**7,830**

[1]Only major bark beetle and mortality agents shown. Agents detected with lesser activity may not be represented in the table.
[2]Values rounded to the nearest 10, sum of individual values may differ from totals due to rounding and multiple agents occurring in the same location; a blank cell indicates no damage was observed.
[3]Values based on landownership, thus any inholdings are summarized with their ownership category.
[4]Ponderosa pine bark beetle attributed mortality may include acreage from similar hosts such as Apache, Arizona, and Chihuahua pines.

Defoliation Summary

Defoliation from insects and diseases (including agents not included in Table 3) decreased slightly across the region from 417,070 acres in 2021 to 303,700 acres in 2022 (Table 3). Most acres with defoliation were detected in New Mexico (86%), on Forest Service land (63%) and attributed to western spruce budworm or ponderosa pine needleminer activity. Detectable western spruce budworm damage decreased in each state and regionwide from 227,740 acres in 2021 to 174,900 acres in 2022. Damage from ponderosa pine needleminer was mapped exclusively in New Mexico and decreased from 100,000 acres with defoliation in 2021 to 30,180 acres in 2022, mostly on private land (61%) and the Carson NF (34%). Aspen damage recorded during aerial surveys includes defoliation, dieback, and mortality. Aspen damage increased across the region from 20,290 acres in 2021 to 26,830 acres in 2022. Most of the observed aspen damage occurred in New Mexico (83%) on the Santa Fe NF (Figure 7). In Arizona, much of the aspen damage was observed on Navajo Nation Tribal Lands and on the Apache-Sitgreaves NFs (Table 3).

Figure 7. Aspen mortality near Tres Lagunas on the Santa Fe National Forest, New Mexico. USDA Forest Service photo.

Nearly 6,000 acres with ponderosa pine defoliation were mapped across the region in 2022 up from just over 1,000 acres recorded in 2021. The damage was attributed to pine sawfly in New Mexico where 2,250 acres were mapped, 70% of which occurred on the Cibola, Gila, and Lincoln NFs. In Arizona, 3,700 acres with ponderosa pine defoliation were mapped, of which 3,670 acres occurred on the Kaibab NF north of Grand Canyon National Park (NP). A specific causal agent was not identified during late summer ground verification surveys on the North Kaibab Ranger District (RD). Additional monitoring will be conducted in 2023. Defoliation and dieback of Gamble oak was mapped regionwide across 6,630 and 3,440 acres respectively. The majority of the defoliation (78%) was observed in New Mexico whereas most of the dieback (56%) was mapped in Arizona.

Douglas-fir tussock moth activity and defoliation increased across the region from zero acres with damage in 2021 to 3,320 acres mapped in 2022. Most of the damage (94%) was observed in New Mexico with 2,920 acres mapped on the Cibola NF and 190 acres on private land. In Arizona, a total of 210 acres with Douglas-fir tussock moth defoliation were observed on the Coronado, Tonto, and Coconino NFs. An isolated outbreak was confirmed on Mount Graham in the Pinaleño Mountains, Coronado NF, and persistent sub-outbreak activity continues in the Pinal Mountain Recreation Area on the Tonto NF. Janet's Looper activity was not observed in the region in 2022.

Damage from sap sucking insects (including agents not included in Table 3) decreased regionwide in 2022. Active damage agents include native pinyon needle scale and exotic spruce aphid and oystershell scale. Observed acres with pinyon needle scale damage were down slightly from 53,740 acres in 2021 to 52,820 acres in 2022 (Table 3). Most of this damage (54%) was detected in New Mexico, where acres with damage more than doubled from 13,690 in 2021 to 28,500 in 2022. Nearly half of the acres with pinyon needle scale damage occurred on the Lincoln and Gila NFs. In Arizona, acres with pinyon needle scale damage decreased from 40,050 in 2021 to 24,320 in 2022. Many areas with pinyon needle scale damage and persistent drought impacts incurred significant mortality that was not directly quantified by aerial surveys. Pinyon needle scale damage accounted for nearly 58% of Arizona's total acres with defoliation. Damage was primarily observed on the Tonto and Prescott NFs and White Mountain Apache Tribal Lands. In 2022, no acres with Prescott scale damage were recorded during the aerial surveys in Arizona. This is down from 1,340 acres detected in 2021 on White Mountain Apache Tribal Lands. Aspen mortality and dieback caused by invasive oystershell scale is persistent and documented during ground surveys in aspen enclosures and permanent plots in Arizona. Approximately 290 acres with dieback have been documented, primarily in northern Arizona on the Kaibab (52%) and Coconino (38%) NFs, and on state and private lands (10%). Defoliation caused by spruce aphid was mapped exclusively in Arizona, where the number of acres with damage decreased from 310 acres in 2021 down to only 10 acres in 2022.

Table 3. Defoliation[1] and aspen damage incidence by ownership (acres) from aerial detection surveys in 2022 in Arizona and New Mexico[2].

Owner[3]	Western Spruce Budworm	Aspen[4] damage	Needle-miner ponderosa	Sawfly-ponderosa	Defoliation-ponderosa	Pinyon needle scale	Tamarisk Leaf Beetle	Douglas-fir Tussock Moth	Defoliation-oak
Apache-Sitgreaves National Forest		930			30	70			
Coconino National Forest	350	440			< 5	2,320		10	70
Coronado National Forest		190						170	
Kaibab National Forest	1,160	360			3,670	610			760
Prescott National Forest						4,260	100		500
Tonto National Forest						7,610	290	30	
Bureau of Land Management		40					80		
Grand Canyon National Park		510				40			
Havasupai Tribal						40			
Hopi Tribal							230		
Navajo Nation	70	1,030					90		
San Carlos Apache						840	210		
White Mtn Apache		850				6,650	740		
State & Private		110				1,860	5,020		130
Arizona Total	**1,580**	**4,470**			**3,700**	**24,320**	**6,760**	**210**	**1,450**
Carson National Forest	56,670	5,400	10,260						
Cibola National Forest	2,040	2,070		1,000				2,920	140
Gila National Forest				530		8,170			
Lincoln National Forest	17,470	580		30		15,250			3,480
Santa Fe National Forest	33,850	8,370	1,610						
Bureau of Land Management	530					160	10		
Bandelier National Monument		60							
Valles Caldera National Preserve	2,050	80							
Isleta Pueblo									50
Jicarilla Apache Tribal	4,130	120							280
Laguna Pueblo							40		
Mescalero Apache Tribal	5,030	150				2,220			670
Navajo Nation	150	1,190							
Santa Clara Pueblo	< 5		40						
Taos Pueblo	5,610	350							
State & Private	45,790	3,990	18,270	690		2,710		190	560
New Mexico Total	**173,320**	**22,360**	**30,180**	**2,250**		**28,500**	**60**	**3,110**	**5,180**
Grand Total	**174,900**	**26,830**	**30,180**	**2,250**	**3,700**	**52,820**	**6,820**	**3,320**	**6,630**

[1]Only major defoliator agents shown. Less commonly detected agents or those with lesser activity may not be represented in the table.

[2]Values rounded to the nearest 10, sum of individual values may differ from totals due to rounding and multiple agents occurring in the same location; a blank cell indicates no damage was observed.

[3]Values based on landownership, thus any inholdings are summarized with their ownership category.

[4]Aspen damage includes a combination of insect defoliation and other biotic and abiotic factors causing aspen decline, dieback, and in some cases mortality.

Disease Summary

Dwarf mistletoe is the most common and widespread pathogen in the Southwest. Because aerial detection surveys do not allow for identification of dwarf mistletoe infestations and yearly ground estimates are limited, the overall estimated acreage affected does not change from year to year. Current estimates (Arizona 1,873,000 acres and New Mexico 2,073,000 acres across all ownerships) are based on historical records, which indicate that over one-third of the ponderosa pine acreage and about one-half of the mixed conifer acreage have some level of infection. Recent roadside surveys showed similar affected area in ponderosa pine compared with these historical records.

Root diseases are also widely distributed across the region (219,000 acres and 860,000 acres across all ownerships for Arizona and New Mexico, respectively), but poorly documented. The most prominent root diseases in the region are caused by *Armillaria* spp. and *Heterobasidion occidentale*, and these diseases often interact with bark beetles, drought, and other tree stressors to cause tree mortality. Foliar diseases generally occur sporadically based on environmental conditions. Disease can be a chronic issue in areas conducive to infection. White pine blister rust, a disease caused by the introduced fungus *Cronartium ribicola*, continues to injure and kill southwestern white and limber pine in the Southwest. Tree mortality from this disease is most prevalent on the Sacramento Mountains of southern New Mexico, but the disease can be found in many parts of the Southwest, including eastern Arizona and parts of northern New Mexico.

Abiotic Summary

Severe to exceptional drought conditions persisted in the Southwest until significant monsoon moisture in July and August reduced drought severity across the region. Due to these conditions, abiotic damage continued to be significantly elevated across the Southwestern Region in 2022 (Table 4). Impacts were documented from woodlands to high elevation forests. Drought-induced discoloration of all conifer species (though primarily ponderosa and pinyon pine) was mapped on 172,790 acres regionwide.

Widespread drought-induced dieback in juniper continued in Arizona and was observed on over 98,850 acres. A large red belt winter injury event that occurred in southern New Mexico in 2021 and affected a variety of conifer species on nearly 7,000 acres across Carrizo Mountain, Sierra Blanca, and the Capitan Mountains of the Lincoln NF and Mescalero Apache Tribal Lands was still apparent across about 910 acres. Widespread mortality was occurring in these areas, although most of the red belt-affected stands had largely recovered. A major blowdown event occurred on the Sangre de Cristo Mountains in New Mexico and impacted over 10,000 acres of spruce-fir stands (Figure 8). Salt damage of ponderosa pine along roadways was also mapped on about 620 acres across the region.

Figure 8. Tree blow-down from wind event on the Sangre de Cristo Mountains, Carson National Forest. USDA Forest Service photo.

Table 4. Abiotic damage[1] incidence by ownership (acres) from aerial detection surveys in 2022 in Arizona and New Mexico[2].

Owner[3]	Juniper crown dieback	Oak crown dieback	Ponderosa[4] branch flagging	Ponderosa drought discolor	Oak drought discolor	Drought discolor all spp.	Windthrow all spp.
Apache-Sitgreaves National Forest	730	30	260			5,160	
Coconino National Forest	31,790	400	1,350			48,000	
Coronado National Forest	1,080				1,980	1,150	
Kaibab National Forest	29,130	340	190	40	60	18,910	
Prescott National Forest	3,020	740			60	2,890	
Tonto National Forest	2,750	< 5	120			10,640	
Bureau of Land Management	4,030	20				360	
Department of Defense	260				390	730	
Canyon De Chelly National Monument							
Chiricahua National Monument	< 5						
Grand Canyon National Park	1,770						
Lake Mead National Recreation Area	20						
Saguaro National Monument					570	60	
Walnut Canyon National Monument						20	
Wupatki National Monument	360						
Havasupai Tribal	760						
Hopi Tribal	1,250						
Hopi Trust Land	230						
Hualapai Tribal	1,030	80					
Navajo Nation	4,250		< 5	570		340	
San Carlos Apache	830	30	< 5			1,910	
White Mtn Apache	770	20	630			740	
Other Tribal							
State & Private	14,780	270	20		100	2,380	
Arizona Total	**98,850**	**1,930**	**2,570**	**610**	**3,160**	**93,280**	
Carson National Forest			< 5	28,950		150	5,880
Cibola National Forest		350		2,150	600		< 5
Gila National Forest			< 5	7,520		260	
Lincoln National Forest				2,870			
Santa Fe National Forest				10,680			< 5
Bureau of Land Management				< 5			
Department of Energy							
Bandelier National Monument							
El Malpais National Monument							
El Morro National Monument							
Pecos National Historical Park							
Valles Caldera National Preserve				20			
Acoma Pueblo				800			
Isleta Pueblo					10		
Jemez Pueblo							
Jicarilla Apache Tribal				940			
Laguna Pueblo							
Mescalero Apache Tribal			< 5	2,050			< 5
Navajo Nation				160			
Picuris Pueblo							
Ramah Tribal							
Santa Clara Pueblo			< 5				30
Taos Pueblo				1,500			1,570
Zia Pueblo							
Zuni Pueblo							
Other Tribal							
Cochiti Pueblo							
Santa Ana Pueblo							10
State & Private		1,160	< 5	16,840	40	210	2,820
New Mexico Total		**1,520**	**< 5**	**74,470**	**650**	**620**	**10,300**
Grand Total	**98,850**	**3,440**	**2,580**	**75,080**	**3,810**	**93,900**	**10,300**

[1]Only major abiotic damage shown. Less commonly detected damage or those with lesser activity may not be represented in the table.

[2]Values rounded to the nearest 10, sum of individual values may differ from totals due to rounding and multiple agents occurring in the same location; a blank cell indicates no damage was observed.

[3]Values based on landownership, thus any inholdings are summarized with their ownership category.

[4]Ponderosa branch flagging includes acres with damage caused by twig beetles, Prescott scale, and general branch flagging with no insect damage.

STATUS OF INSECTS

Douglas-fir tussock moth larva feeding on Engelmann spruce
USDA Forest Service photo

Status of Major Insects

Bark Beetles

The overall total acreage with tree mortality attributed to bark beetles decreased across the region in 2022 (Table 2). In contrast, acres with bark beetle-caused pinyon pine mortality increased, with most of the damage located on the Kaibab NF (18%) and Navajo Nation tribal lands in Arizona (17%). In New Mexico, bark beetle-related tree mortality was highest on private lands (15%) and on Navajo Nation tribal lands (10%). Bureau of Land Management lands across the region accounted for 5% of recorded pinyon mortality. Bark beetle-caused ponderosa pine mortality decreased in Arizona, but increased slightly within New Mexico and was mapped on 310,160 acres regionwide. Most of the ponderosa pine mortality was mapped on the Gila NF (27%) in New Mexico and the Coconino NF (22%) in Arizona. White fir mortality, caused by fir engraver, increased dramatically in Arizona, with damage predominantly located on the Kaibab NF (35%) and within Grand Canyon NP (16%). The highest percentage of fir engraver-caused tree mortality in New Mexico was located on the Santa Fe NF (5%). Douglas-fir mortality, caused by the Douglas-fir beetle, decreased slightly with over 90% of the mortality observed within New Mexico. Locations with the highest proportion of Douglas-fir mortality were on the Santa Fe (43%), Carson (16%), Cibola (6%), and Gila (6%) NFs in New Mexico, and on the Kaibab NF within Arizona (3.5%). Corkbark fir mortality, caused by the western balsam bark beetle, increased regionwide with over 90% occurring in Arizona. Locations with the highest corkbark fir mortality were the Kaibab NF (45%) and Grand Canyon National Park (33%) in Arizona, and on Navajo Nation tribal lands (6%) in New Mexico. Spruce mortality, caused by spruce beetle, decreased from 2021 values across the region and over 98% of mortality occurred within New Mexico; mostly on the Carson NF (64%). Bark beetles remain the leading cause of mortality within regional coniferous forests although drought, climate, disease, and the synergistic contributions between stressors can be difficult to quantify.

Pinyon-Juniper Woodlands

Acres with bark beetle-attributed mortality nearly tripled in pinyon-juniper woodlands during 2022 (Figure 9). Some of this increase is due to surveys of additional areas in New Mexico. The total area with bark beetle mortality observed in the pinyon-juniper woodlands increased from 135,780 acres in 2021 to 355,900 acres in 2022. The damage was almost equally divided between Arizona (47%) and New Mexico (53%).

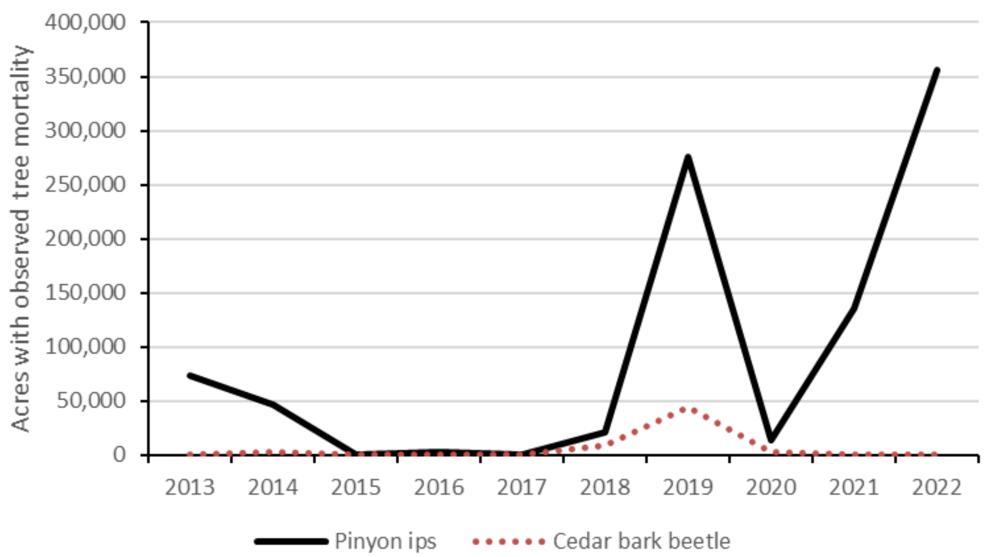


Figure 9. Pinyon-juniper mortality associated with ips and cedar bark beetles in the Southwestern Region over the last ten years.

Pinyon Ips

Ips confusus
Host: Pinyon pine

Acres with pinyon mortality increased almost three-fold from 135,780 acres in 2021 to 355,900 acres in 2022 and increased nearly 25-fold over 2020 mortality data (Table 2, Figure 9). Special early season survey flights were conducted due to observed mortality resulting in a larger area of pinyon-juniper woodland coverage than in typical years (Figure 10). Similar levels of pinyon mortality were observed within New Mexico (53%) and Arizona (47%) and the regional total rose from 135,780 acres in 2021 to 355,900 acres in 2022. The Kaibab NF (18%) and Navajo Nation tribal lands (17%) accounted for the greatest proportion of pinyon mortality in Arizona. Private lands (15%) and Navajo Nation tribal lands (10%) contained the greatest proportion of mortality within New Mexico (Table 2). The Kaibab NF contained 65,150 acres with pinyon mortality, while acres mapped on Navajo Nation tribal lands in Arizona increased from 8,010 acres in 2021 to 61,040 acres in 2022. In New Mexico, pinyon mortality on Navajo Nation tribal lands increased from 15,830 acres in 2021 to 35,830 acres in 2022; acres on state and private lands with pinyon mortality across the region increased from 22,090 acres in 2021 to 73,930 acres in 2022.

Figure 10. Pinyon mortality in the Datil Mountains, Cibola National Forest, New Mexico. USDA Forest Service photo.

Cedar Bark Beetles

Phloeosinus spp.
Host: Junipers and Arizona cypress

Juniper mortality has historically been linked to cedar bark beetle activity in the Southwest and ground surveys in 2022 found many dead alligator junipers with evidence of attack. However, in recent years, dieback appears to be largely attributed to drought. Cedar bark beetle activity was only directly associated with 30 acres of mortality in Arizona, exclusively on the Coronado NF, and 520 acres in New Mexico, predominantly on private lands and within the Gila NF. Additionally, Lincoln NF and other NFS personnel visited the Guadalupe Mountains in early 2022 and did observe cedar bark beetles playing a role in the dieback occurring there. For more information see the Abiotic section.

Juniper Twig Pruner
Styloxus bicolor
Host: Junipers

The juniper twig pruner is a native longhorn beetle that causes tip dieback during dry periods. In 2021, drought conditions contributed to large stands of juniper branch flagging and associated juniper twig pruner activity on the Chino Valley Ranger District of the Prescott NF in Arizona. In 2022, the damage on the Prescott NF seems to have declined; however, damage was noted in Coconino and Apache Counties. Within New Mexico, in 2022, juniper twig pruner was observed during a site visit near El Rito, Carson NF, and on Santa Ana Pueblo tribal lands. Damage from juniper twig pruners usually results in minor damage.

Ponderosa Pine Forest Type

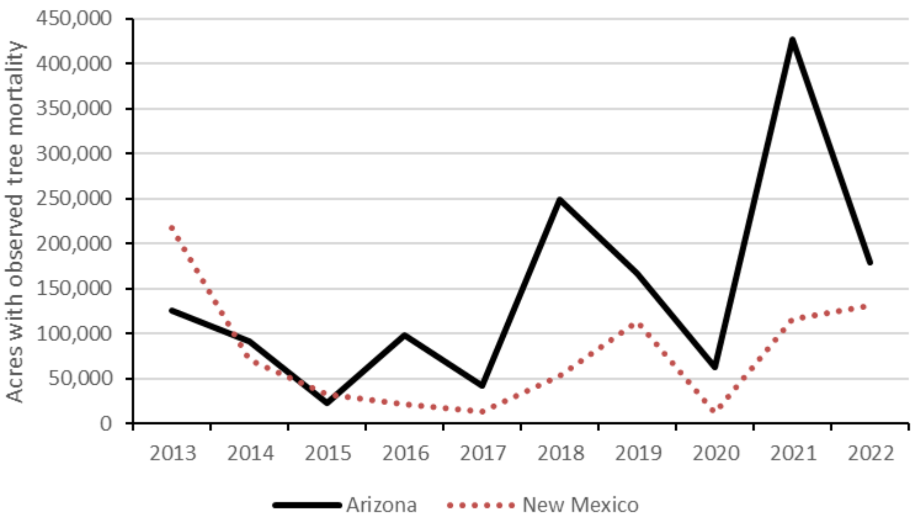


Figure 11. Ponderosa pine mortality attributed to bark beetles in the Southwestern Region over the last ten years.

Figure 12. Bark beetle-attacked ponderosa pine in Arizona. USDA Forest Service photo.

In the Southwestern Region, ponderosa pines encounter a diverse complex of bark beetles, most commonly in the *Ips* and *Dendroctonus* genera. These beetles overlap geographically, and it is quite common to find several species co-occurring within the same tree.

Ponderosa pine mortality decreased throughout most of the region, with 310,000 acres mapped in 2022 compared to 543,000 acres in 2021 (Figure 11). The majority of the damage (58%) occurred in Arizona with 177,540 acres. Most of the mortality mapped in Arizona was located on the Coconino NF (Figure 12), but mortality there was reduced to 67,020 acres in 2022 from 165,660 in 2021.

In New Mexico, ponderosa pine mortality increased from 116,080 acres in 2021 to 130,710 in 2022 (Table 2). Most of the mortality in New Mexico (64%) was located on the Gila NF. The remaining mortality was scattered throughout various other federal, state, and private lands with moderate levels located within the Cibola NF (10%).

Mixed Conifer Forest Type

Mortality is occurring in mixed conifer forests (primarily consisting of Douglas-fir and white fir) throughout the Southwestern Region. Increased mortality often occurs when trees experience periods of drought, fire, disease, and insect activity. Douglas-fir and white fir mortality increased in 2022 with approximately 76,000 total acres with mortality mapped. White fir had the largest increase in acres with mortality, especially in Arizona where over 42,900 acres with white fir mortality were documented (85% of total regional damage; Table 2).

Douglas-fir Beetle

Dendroctonus pseudotsugae
Host: Douglas-fir

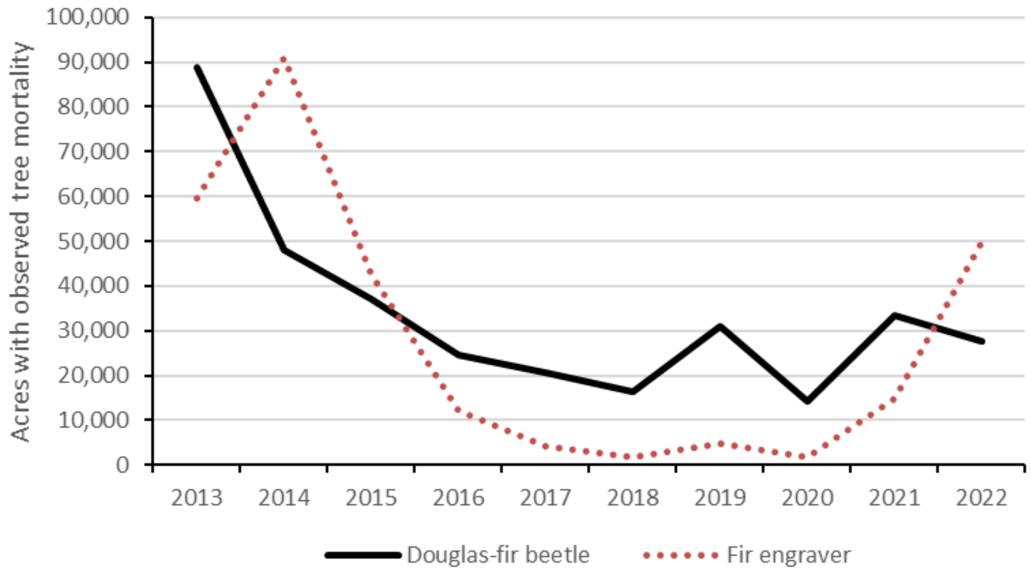


Figure 13. Mixed conifer mortality associated with Douglas-fir and fir engraver in the Southwestern Region over the last ten years.

Douglas-fir beetle activity is most common in dense stands of mature Douglas-fir. At endemic levels, Douglas-fir beetles will target stressed trees such as those injured by fire, infected by dwarf mistletoe or root disease, or trees experiencing severe defoliation or drought stress. Generally, Douglas-fir beetle will only affect small pockets or individual trees, but infestations may grow to larger outbreaks. In 2022, Douglas-fir mortality from Douglas-fir beetle decreased slightly across the region from 33,360 acres mapped in 2021 to 27,680 in 2022 (Figure 13). New Mexico accounted for 91% of the total Douglas-fir beetle activity. Concentrations of mortality were highest on the Santa Fe NF in New Mexico where 11,930 acres with mortality were mapped in 2022 (Table 2). Douglas-fir mortality attributed to Douglas-fir beetle decreased by around 50% in Arizona, where only 2,430 acres of mortality were mapped in 2022. 980 of these acres were within the boundary of the Kaibab NF, accounting for the highest concentrations within Arizona.

Fir Engraver

Scolytus ventralis
Hosts: White fir, corkbark fir

Fir engraver-caused mortality is often linked to root disease and drought-stressed trees growing in dense stands on warm, dry sites in the Southwest. The resulting tree mortality may be more prevalent on drier south- and west-facing slopes. Mortality can occur in all size and age classes.

Figure 14. Fir engraver-caused tree mortality on the Kaibab NF, Arizona. USDA Forest Service photo.

White fir mortality attributed to fir engraver increased considerably regionwide, with total acres mapped rising from 14,880 in 2021 to 49,780 in 2022 (Figure 13). In Arizona, fir engraver activity and associated white fir mortality increased dramatically in 2022 compared to 2021. Most of the damage (40%) was observed on the Kaibab NF (Figure 14). In addition, substantial damage was observed on the Coconino NF, Grand Canyon NP, and White Mountain Apache Tribal Lands. In New Mexico, white fir mortality attributed to fir engraver increased in 2022 to more than double the amount observed in 2021. Mortality was observed primarily on the Santa Fe and Cibola NFs, particularly on the Sandia RD, Cibola NF and on the Pecos-Las Vegas RD, Santa Fe NF. The elevated activity is likely a result of recent drought stress and root disease that has weakened trees in these areas. The mortality on the Cibola NF also is related to a Douglas-fir tussock moth outbreak that heavily defoliated parts of the Sandia Mountains in the late 2010s.

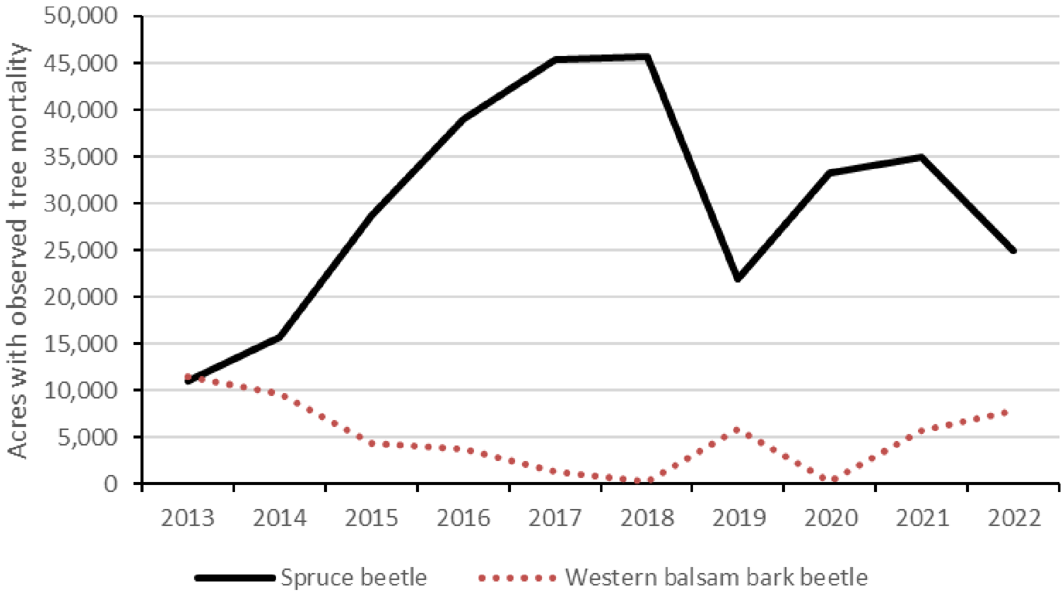


Figure 15. Tree mortality in spruce-fir forests attributed to spruce beetle and western balsam bark beetle in the Southwestern Region in the last ten years.

Spruce-fir Forest Type

At around 9,000' elevation, mixed conifer forests start to transition to spruce-fir forests. Engelmann spruce and corkbark fir are the primary tree species, but blue spruce, southwestern white and limber pines, Rocky Mountain bristlecone pine, and aspen may also be present.

Spruce Beetle

Dendroctonus rufipennis
Host: Spruce

Regional spruce mortality attributed to spruce beetle decreased from 34,930 acres in 2021 to 24,980 in 2022 (Figure 15). Spruce beetle activity in Arizona was minimal in 2022 with only 330 acres of mortality documented from aerial surveys. The majority of the activity (75%) was mapped on the Kaibab NF. Forest Health Protection staff in Arizona have been monitoring spruce beetle populations using baited funnel traps on the Apache-Sitgreaves NF for several years due to concerns that ongoing spruce aphid defoliation may cause a subsequent bark beetle outbreak. This trapping was discontinued in 2022 due to low activity and low trap catches in 2021.

New Mexico accounted for almost 99% of bark beetle-caused spruce mortality regionwide. Within New Mexico, most of the spruce mortality was mapped on the Carson (65%) and Santa Fe (34%; Figure 16) NFs. Aerial surveys in 2022 mapped a decrease in area affected compared to 2021, mostly due to wildfire burning through spruce beetle-infested stands. The area affected slightly increased on the Carson NF and was reduced by half on the Santa Fe NF. Some of the stands that have experienced several years of spruce beetle have recorded >90% spruce mortality and little new activity was observed in these severely affected areas. Minor activity was recorded on state and private lands.

Figure 16. Spruce beetle-caused tree mortality (yellow-orange, bronze, and grey trees) near Ski Santa Fe in the Santa Fe National Forest, New Mexico. USDA Forest Service photo.

Western Balsam Bark Beetle

Dryocoetes confusus
Hosts: Subalpine and corkbark fir

Corkbark fir mortality attributed to western balsam bark beetle increased regionwide from 5,780 acres in 2021 to 7,830 in 2022 (Figure 15). Most of the mortality attributed to western balsam bark beetle was observed in Arizona, which accounted for 93% of the damage, and the majority of corkbark fir mortality within the state occurred on the Kaibab NF (48%) and in Grand Canyon NP (33%). Fir engraver also can cause corkbark fir mortality, particularly in the White Mountains of Arizona.

Figure 17. Western balsam bark beetle-killed corkbark fir in the Chuska Mountains, Navajo Nation, New Mexico. USDA Forest Service photo.

New Mexico acreage affected by western balsam bark beetle decreased slightly, falling from 770 acres in 2021 to 560 in 2022. The majority of the area affected was located on Navajo Nation tribal lands (84%; Figure 17). Pockets of mortality within the state also were noted on Mescalero Apache tribal lands (9%). Activity on state and private lands remained low with only 10 acres mapped in 2022. This bark beetle commonly interacts with root diseases caused by *Armillaria* spp. or *Heterobasidion occidentale* to kill trees. The interaction of bark beetles and root disease is common in many forests throughout the West, and signs of infection by *Armillaria* spp. can be consistently found on dead corkbark fir trees in many spruce-fir forests across the region. Armillaria-associated mortality is particularly severe and common in the Sandia Mountains of the Cibola NF and Sangre de Cristo Mountains of the Santa Fe NF.

Defoliators

Defoliation damage in 2022 ranged from removal of foliage to crown discoloration, dieback, and branch flagging. Acres observed with damage from defoliators (including less prominent agents not included in Table 3) decreased slightly regionwide from 417,070 acres in 2021 to 303,700 in 2022 (Table 3). Regionally, acres with defoliation attributed to spruce aphid decreased to nearly zero while Douglas-fir tussock moth (DFTM) defoliation increased from zero acres observed in 2021 to 3,320 acres observed in 2022. Janet’s looper was not observed in 2022. Aspen damage, including defoliation, dieback, and mortality, increased regionwide to 26,830 acres in 2022 from 20,290 acres in 2021 regionwide. The majority of the acres with aspen damage (83%) were mapped in New Mexico, mostly on the Santa Fe, Carson, and Cibola NFs, with nearly 4,000 acres on state and private lands. Ponderosa pine needleminer activity dropped from 100,000 acres in 2021 to 30,180 in 2022, all in New Mexico and mostly on state and private lands and the Carson and Sante Fe NFs. Pine sawfly defoliation in ponderosa pine was on twice as many acres in 2022 than in 2021, with all 2,250 acres occuring in New Mexico. Western spruce budworm continues to cause the most acreage of defoliation compared to other agents in the region. However, the number of acres with damage decreased for the second year in a row, from 227,740 in 2021 to 174,900 in 2022. Nearly all of the budworm caused damage was observed in northern New Mexico, where the host type is more prevalent, except for 1,580 acres mapped north of Grand Canyon National Park in Arizona.

Pinyon-Juniper Forest Type

Pinyon Needle Scale

Matsucoccus acalyptus
Host: Pinyon pine

Pinyon needle scale infestations are persistent in many pinyon woodlands throughout the region and repeated defoliation caused by this insect can cause reduced growth and stunted needles. In severe outbreaks, small trees may be killed. While chronic in many places, the amount of visible defoliation varies from year-to-year. Depending upon the severity of the defoliation and timing of ground visits and survey flights, this damage can be quite difficult to detect from the air and thus numbers may vary from year-to-year. Acres with damage attributed to pinyon needle scale decreased in 2021 from 53,740 to 52,820 acres in 2022 regionwide (Table 3).

In Arizona, approximately 40% fewer acres (24,320) were detected with pinyon needle scale damage in 2022 than during 2021 (40,050 acres). This decline in acres observed in Arizona coincided with improved drought conditions away, as well as an absence of special surveys in woodlands during 2022. Most of the damage was detected on the Tonto and Prescott NFs, and on White Mountain Apache Tribal Lands. The decline in acres with damage may also be due to the significant amount of pinyon mortality, which obscures the more subtle pinyon needle scale signature. Arizona Department of Forestry and Fire Management conducted ground validation of severe pinyon drought polygons following aerial surveys that also determined significant amounts of pinyon needle scale activity occurring in the woodlands on the Clifton RD, Apache-Sitgreaves NF. Federal and private lands were impacted surrounding Honeymoon Campground and Eagle Creek.

Approximately half of the regionwide damage (54%) was detected in New Mexico, where the area mapped with pinyon needle scale activity more than doubled from 13,690 acres in 2021 to 28,500 in 2022. This increase was mostly observed on the Lincoln NF. Damage was also mapped to a lesser extent on the Gila NF. Populations are likely persisting in these locations. The increased area mapped with pinyon needle scale may also be exacerbated by the increased in aerial survey coverage of pinyon juniper woodlands and the extended drought conditions of 2020-22.

Ponderosa Pine Forest Type

Pine Sawflies

Neodiprion spp. and *Zadiprion* spp.
Host: Ponderosa pine

In New Mexico, 2,250 acres with ponderosa pine defoliation attributed to pine sawflies was mapped, which was more than double the 1,050 acres recorded in 2021. Seventy percent of this damage occurred on the Cibola, Gila, and Lincoln NFs. Acres with defoliation on the Cibola NF increased from zero acres in 2021 to 1,000 in 2022, while activity on the Gila NF increased from 140 acres in 2021 to 530 in 2022. On state and private lands, 690 acres of defoliation by pine sawflies were mapped, down from 910 acres in 2021. No pine sawfly defoliation was mapped in Arizona during 2022; however, there was ponderosa pine defoliation where no causal agent was verified (see below).

Figure 18. Ponderosa pine defoliation caused by an unknown defoliator on the Kaibab Ranger District, Kaibab NF. USDA Forest Service photo.

Unknown Defoliator

Host: Ponderosa pine

In Arizona, severe and widespread defoliation of ponderosa pine was observed during the 2022 aerial detection survey over the North Kaibab RD, Kaibab NF where approximately

3,700 acres were mapped. Aerial surveys were conducted in late August and followed by a field visit and no cause was found (Figure 18). Potential defoliators could be pandora moth, pine butterfly, or pine sawflies. Monitoring will continue next spring and summer to look for a causal agent associated with the defoliation. Aspen in the area was also severely defoliated and severe drought has persisted in this part of the state possibly exacerbating defoliation symptoms.

Pandora Moth

Coloradia pandora
Host: Ponderosa pine

Pandora moth has a 2-year life cycle, with feeding and moth flight occurring in alternate years, so that most of the defoliation occurs every other year. There are no current outbreaks of this insect to report; however, adult pandora moths were observed in Arizona at Jacob Lake on the Kaibab Plateau and at Mingus Mountain on the Prescott NF in July 2022. No observations of pandora moth were reported in New Mexico.

Pine Needleminer

Coleotechnites ponderosae
Host: Ponderosa pine

The ponderosa pine needleminer outbreak that caused a large area of discolored ponderosa pine over the past five years on state and private lands in the northeastern part of New Mexico continued in 2022. However, acres observed with damage decreased from 100,000 in 2021 to 30,180 in 2022, mostly on private land (61%) and the Carson NF (34%). Most of this damage is still on the Vermejo Park Ranch. Needleminer appears to be the primary agent of the damage; however, it is unclear if needleminer is solely responsible for the activity over the entire area on Vermejo Park Ranch. Another area of discolored ponderosa pine mapped on the Carson NF near Tres Piedras was confirmed to be needleminer activity. Needleminer was also observed on Santa Clara Pueblo tribal lands and other parts of the Jemez Mountains in 2022. The surrounding areas with ponderosa pine discoloration and defoliation appear to be drought stressed and evidence of twig beetle attacks also were confirmed. No needleminer activity was observed in Arizona in 2022.

Prescott Scale

Matsucoccus vexillorum
Host: Ponderosa pine

In 2022, we did not report any acres with specific Prescott scale damage during the ADS in Arizona. This is down from 1,340 acres detected in 2021 on White Mountain Apache Tribal Lands. Aerial observers detected 630 acres with ponderosa pine branch/tip flagging on White Mountain Apache Tribal Lands (where Prescott scale damage has historically occurred) in 2022; however, several agents including twig beetles, drought, and Prescott scale were likely contributing to the damage symptoms. These symptoms were widespread in young stands of advanced regeneration and young pole stands. The damage symptoms were simply recorded as branch flagging in ponderosa with multiple contributing factors in the White Mountains. Reduced drought severity in the White Mountains in 2022 may have also reduced the impacts associated with twig dieback from scale feeding compared to last year's damage. Branch and tip flagging in ponderosa pine has decreased substantially in Arizona, from 11,250 acres reported statewide in 2021 to only 2,570 acres with damage in 2022. Twig beetles and drought are the dominant causal agents/factors responsible for tip and branch flagging in ponderosa pine in 2022.

Mixed Conifer Forest Type

Aspen Defoliation, Dieback, and Mortality

Western tent caterpillar, *Malacosoma californicum*
Large aspen tortrix, *Choristoneura conflictana*
Oystershell scale, *Lepidosaphes ulmi*
Black leaf spot, *Drepanopeziza populi-albae*
Complex of drought and other insects and diseases

In the Southwestern Region, aspen mortality and defoliation are monitored through a combination of aerial and ground efforts. Aspen damage, which includes defoliation, dieback, and mortality, increased across the region from 20,000 acres in 2021 to 26,830 in 2022. Over 80% of the aspen damage mapped via aerial detection surveys occurred in New Mexico in 2022. Most of this damage was mapped north of Interstate 40, particularly on Navajo Nation tribal lands (Figure 19) and on the Carson and Santa Fe NFs. In Arizona, most of the aspen damage was detected on Navajo Nation tribal lands and on the Apache-Sitgreaves NFs and neighboring White Mountain Apache Tribal Lands (Table 3).

The number of acres with aspen damage increased in New Mexico during from 15,490 in 2021 to 22,360 in 2022. Most of the defoliation recorded during aerial surveys was observed on the Santa Fe NF. Western tent caterpillar is often the primary defoliating agent, however, large aspen tortrix contributes to the defoliation as it was also found in several sites on the Carson NF.

Figure 19. Aspen mortality and defoliation on the Chuska Mountains, Navajo Nation, New Mexico. USDA Forest Service photo.

Aspen stands along the Hyde Park Road on the Santa Fe NF experienced another year of defoliation. Populations of western tent caterpillars have been extensive in this area and on several recreation sites. However, trees have been re-foliating each year following the defoliation and no tree mortality has been observed to date. Repeated defoliation from western tent caterpillar will likely result in reduced radial growth. Evidence of severe defoliation can be noted by the presence of old tents in branches and cocoons along tree boles and on understory vegetation.

In Arizona, ongoing ground surveys and a network of permanent monitoring plots are used to evaluate impacts from invasive oystershell scale (OSS) and other native insects and diseases on aspen regeneration, recruitment and overstory tree health. Aspen mortality and dieback is severe in the Southwestern Region and are shown to be driven by several factors including persistent drought, wild ungulate browse, fire suppression, and native insects and diseases. Dieback and mortality have been most severe in stands located on low elevation south/west facing slopes and stands experiencing chronic ungulate browse.

OSS has been placing further stress on aspen regeneration in Arizona, which is often lacking on the landscape. Damage from OSS is persistent on a site until it is treated. Examination of aspen enclosures in Arizona detected 290 acres with persistent OSS damage. Nearly 200 aspen enclosures were evaluated and over 50% are infested with OSS. For more on OSS see the special project section.

Douglas-fir Tussock Moth

Orgyia pseudotsugata
Hosts: True firs, Douglas-fir, and spruce

Douglas-fir tussock moth was active in New Mexico and Arizona in 2022. Large and extensive outbreaks were documented in mixed conifer forests on the Cibola NF in New Mexico and a smaller isolated outbreak was documented on Mount Graham in the Coronado NF near Safford, Arizona. The region went from no acres with Douglas-fir tussock moth defoliation in 2021 to 3,320 acres mapped in 2022. Most of the damage (94%) was mapped in New Mexico with 2,920 acres mapped on the Cibola NF and the remaining 190 acres on private land. In Arizona only 210 acres with DFTM defoliation were observed across the Coronado, Tonto, and Coconino NFs. 80% of this damage mapped on the Coronado NF.

In New Mexico, a Douglas-fir tussock moth outbreak was mapped during aerial detection surveys and confirmed during ground surveys on the Manzano Mountains, Mountainair RD, Cibola NF (Figure 20). The defoliation associated with this outbreak covered roughly 3,000 acres around the southeastern tip of the Manzano Mountains. All life stages of the insect were observed with egg mass surveys conducted over winter indicating that the current outbreak will likely continue into 2023. Severe defoliation has occurred near Red Canyon Campground and is visible from the ground and air. White fir, Douglas-fir, and even some ponderosa pines were severely defoliated.

Captures of male Douglas0fir tussock moth on Sandia Crest Road, Sandia RD, Cibola NF indicate the potential for an outbreak. However, egg mass surveys at recreation sites where trapping occurred did not reach levels that would indicate a site-specific outbreak. Captures of male Douglas-fir tussock moth on Hyde Park Road, Espanola RD, Santa Fe NF also indicated a potential outbreak, but egg mass surveys resulted in very low numbers and defoliation was hard to observe.

Defoliation by Douglas-fir tussock moth increased in southeastern Arizona in 2022, with a small, isolated outbreak occurring along the Scenic Swift Trail Highway at the southeastern edge of Mount Graham. Larval and egg mass sampling suggest the outbreak is collapsing due to a cyclical endemic virus. However, there is already significant defoliation of white fir and Douglas-fir in areas that overlap with the endangered Mount Graham red squirrel habitat. Large diameter Douglas-fir are important midden trees. Early warning pheromone trapping was expanded to lower elevation sites on the southeastern side of the range due to this outbreak. Populations of Douglas-fir tussock moth also continue to fluctuate in the Pinal Mountains where early warning pheromone trap catches remain high (above 50 moths/site average). Follow up

Figure 20. Douglas-fir tussock moth-caused defoliation on the Mountainair Ranger District, Cibola NF, New Mexico. USDA Forest Service photo.

larval sampling in 2022 suggest the population is sub-outbreak and being controlled by parasitoids. Significant defoliation was not observed this year, but light levels of defoliation have been mapped at this location during recent years. Monitoring of this site will continue with pheromone trapping and follow up larval sampling is planned for 2023.

In 2022, FHP staff in Arizona expanded early warning trapping sites to include the North Rim of Grand Canyon NP near the North Kaibab RD section of the Arizona Trail. This was not a historic early warning trapping site, but Park staff observed Douglas-fir tussock moth larvae in the area in early July and so it was included in the 2022 early warning trapping program. Trap catches were relatively high at the trailhead site (14 moths/site average) and near the picnic and campground site (10 moths/site/average). These new sites will be maintained in the annual monitoring program. Early warning trap catches also increased on the Tonto NF in the Sierra Ancha Mountains at the Workman Creek site. Trap catches increased from zero moths trapped in 2021 to an average of 11 moths/site in 2022. This is a historic outbreak site and monitoring will continue for this this site via pheromone trapping and with follow up larval sampling as needed.

Western Spruce Budworm

Choristoneura freemani
Hosts: True firs, Douglas-fir, and spruce

Western spruce budworm activity decreased across the Southwestern Region from 227,740 acres in 2021 to 174,900 acres in 2022 (Table 3), continuing a downward trend in damage attributed to this insect starting in 2021 (Figure 21).

In Arizona, few acres are impacted by western spruce budworm given the lack of contiguous host type in the state. The number of acres with western spruce budworm had been increasing in Arizona during the past few years but in 2022 acres with damage declined to approximately one third of the acres reported in 2021. Most of the damage was mapped north of Grand Canyon NP on the Kaibab NF near Dry Park and DeMotte Park. A small number of acres were also detected on the San Francisco Peaks, Coconino NF near Flagstaff, Arizona. Ground observations of western spruce budworm were validated on the Kaibab NF and on the San Francisco Peaks. A large proportion of acres with presumed western spruce budworm were reported in the White Mountains of Arizona in 2021. However, the damage was most likely associated with drought as budworm was not observed in a few polygons that were later ground validated. The crown discoloration was not observed in 2022 in the White Mountains.

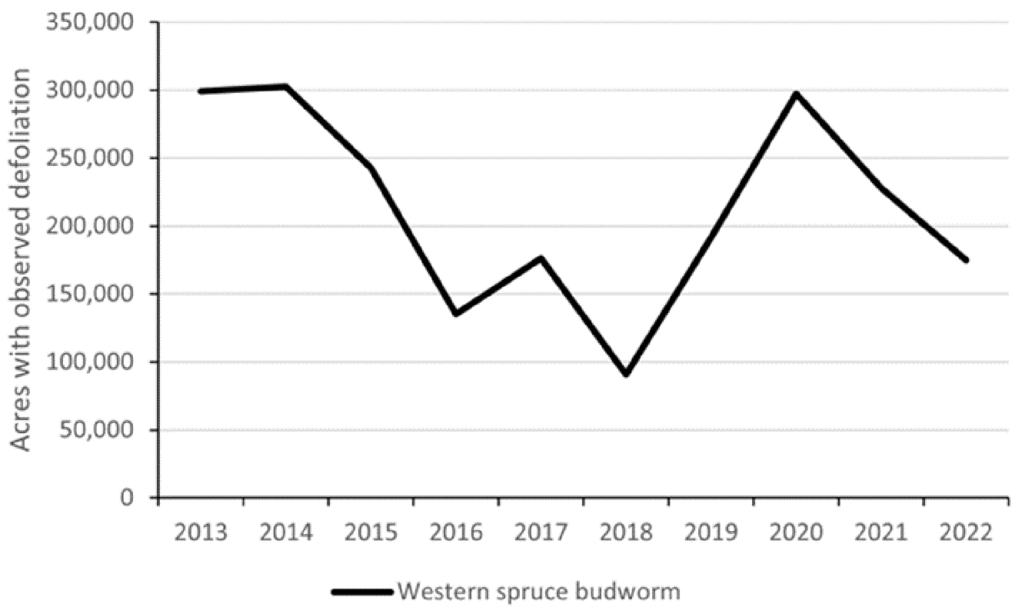


Figure 21. Defoliation attributed to western spruce budworm in the Southwestern Region for the last ten years.

Acres mapped with defoliation from western spruce budworm decreased in New Mexico again in 2022. However, large amounts of western spruce budworm-caused defoliation were still observed in many stands. Most WSBW-caused defoliation occurs in the northern part of the state, particularly on the Carson and Santa Fe NFs and adjacent state and private lands. Elevated levels of defoliation have been observed in mixed conifer and spruce fir stands in this area for the past four decades. Douglas-fir has been the preferred host although white fir and Engelmann spruce are also commonly defoliated. Twig dieback, top-kill, and tree mortality have resulted from the continuous defoliation and understory regeneration has been significantly affected in some stands.

Spruce-fir Forest Type

Spruce Aphid

Elatobium abietinum
Hosts: Engelmann and blue spruce

Spruce aphid is an exotic invasive insect that can cause significant damage and mortality of Engelmann spruce. Acres of defoliation from spruce aphid decreased in Arizona from 310 in 2021 to only 10 in 2022, all on White Mountain Apache Tribal Lands. Acres with defoliation from this insect decreased for a fourth consecutive year in 2022 after spiking in 2016 and 2018 (Figure 22).

Spruce aphids and defoliation of Engelmann spruce were observed from the ground along the Aspen Trail at Arizona Snowbowl on the San Francisco Peaks, Coconino NF during late summer. No spruce aphid activity was observed in New Mexico in 2022. The most recent spruce aphid activity observed in New Mexico was reported at Ski Apache on the Lincoln NF during the winter of 2018-2019. At that time, ground visits identified feeding damage and some live aphids; no damage has been reported in New Mexico recently.

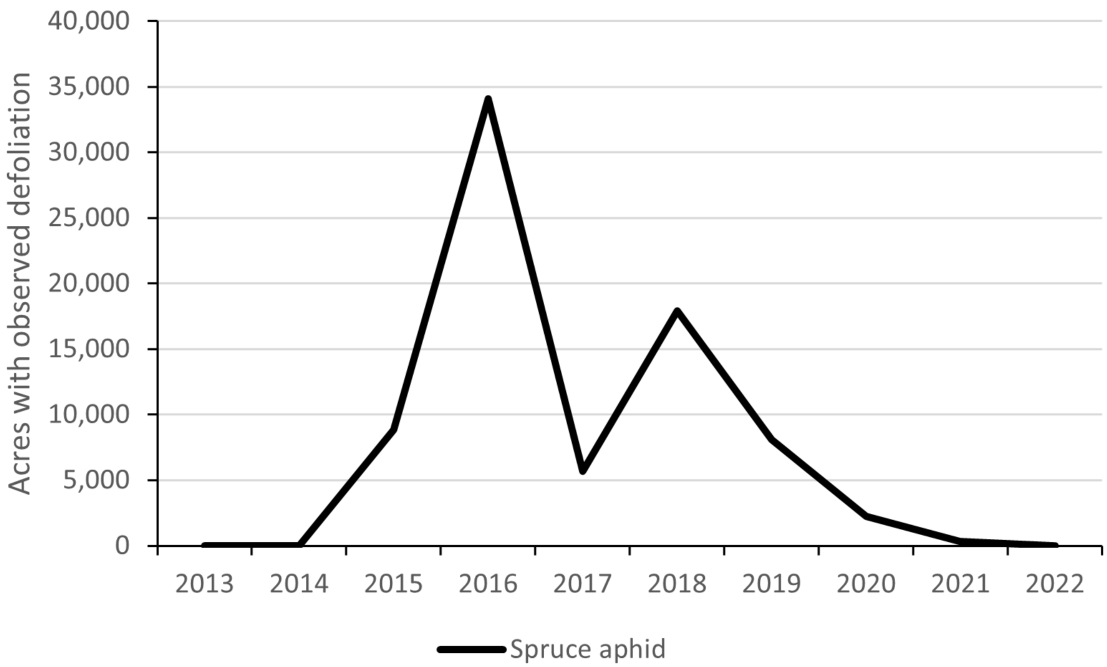


Figure 22. Defoliation attributed to spruce aphid in the Southwestern Region over the last 10 years.

Miscellaneous Insects

Aspen Bark Beetle

Trypophloeus populi
Host: Aspen

Aspen bark beetle activity was noted in Arizona during 2022. Aspen bark beetles, mainly *Trypophloeus populi* mass attacked individual mid-to large diameter aspen trees in several areas in Arizona including in high elevation forest types like on the San Francisco Peaks, Coconino NF (Figure 23) and near Greens Peak, Apache-Sitgreaves NFs and north of the Grand Canyon on the Kaibab NF. The species is known to cause damage in stressed aspen. Short larval galleries are packed with frass and stained brownish black with symbiotic fungi as larvae mature.

Figure 23. Large diameter aspen mass attacked by *Trypophloeus populi* on the San Francisco Peaks, Coconino NF, Arizona. USDA Forest Service photo.

Aspen Blotchminer

Phyllonorycter apparella
Host: Aspen

Blotch miner continues to be observed causing foliar damage and defoliation of aspen regeneration in Arizona. Observations have been made on Tower Mountain and in a large aspen stand near Copper Basin Road on the Prescott NF. Infestations were also observed within the Museum Fire burn scar on and around Mount Elden, Coconino NF. In 2022, a severe blotch miner infestation was observed in aspen regeneration within the Frye Fire footprint near Webb Peak, Coronado NF. Many trees of sapling size exhibited greater than 50% crown infestation on this site. In New Mexico, a small infestation of aspen blotch miner was discovered during ground surveys on the Jemez Ranger District of the Santa Fe NF (Figure 24).

Figure 24. Blotchminer feeding damage on aspen on the Jemez Ranger District, Santa Fe NF. USDA Forest Service photo.

Goldspotted Oak Borer

Agrilus auroguttatus
Hosts: Emory oak, silverleaf oak

Acres of drought stressed Emory and silverleaf oaks with goldspotted oak borer damage decreased in 2022 to only 320 acres. The damage was mapped exclusively in Arizona with most damage mapped on the Sierra Vista RD, Coronado NF. Large decreases were observed on the Nogales and Santa Catalina RDs, Coronado NF. Dieback, discoloration, and mortality of oaks was mapped at low levels across much of the host type in 2022, likely due to drought relief following two active monsoons in Arizona. Ground surveys indicate the pathogens *Biscogniauxia mediterranea* and another currently undescribed *Biscogniauxia* sp. play an important role in the decline of many Emory and silverleaf oak stands. This agent is not discernable during ADS flights, although it appears to be widespread in drought impacted oak woodlands. It is unclear how large of a role these pathogens play in the damage mapped via ADS. Typically, goldspotted oak borer is a secondary pest in drought affected oaks stands.

Spruce Engraver Beetles

Ips spp.
Host: Spruce

In Arizona, individual trees and small groups of Engelmann spruce mortality were associated with spruce engraver beetles on the North Kaibab RD, Kaibab NF (Figure 25) and in the White Mountains on tribal lands and on neighboring Apache-Sitgreaves NFs. Spruce mortality originally mapped as spruce beetle (*Dendroctonus rufipennis*) was changed to spruce engravers following site visits to the area. Spruce engravers were also mapped on White Mountain Apache Tribal Lands during ADS and ground visits on the Apache-Sitgreaves NF. Drought and top kill continue to affect small numbers of individual trees and groups of Engelmann spruce in the White Mountains. Spruce engraver beetles were often found in spruce trees previously defoliated by spruce aphid near Greens Peak on the Springerville RD, Apache-Sitgreaves NF.

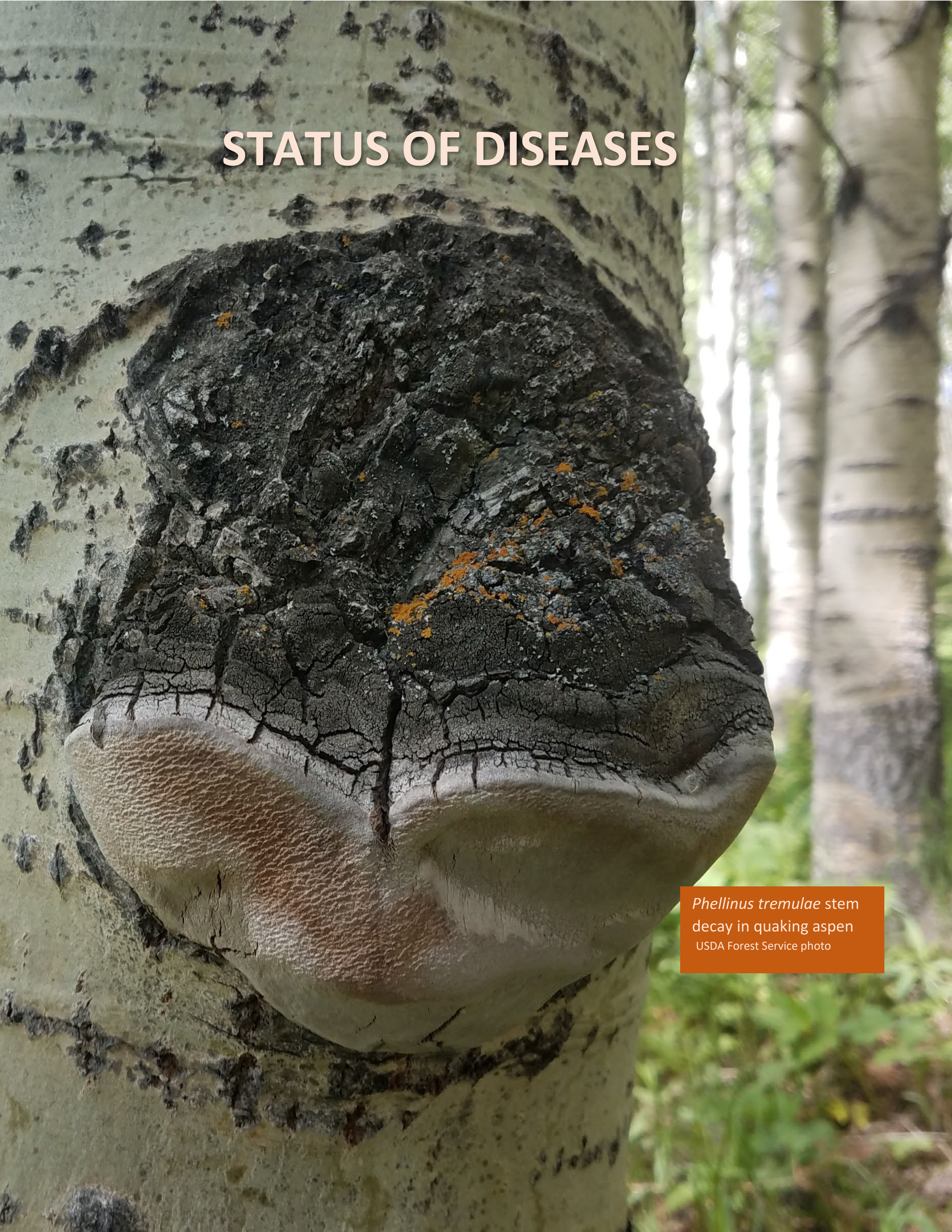
Figure 25. Spruce engraver galleries discovered on the North Kaibab Ranger District, Kaibab NF, Arizona. USDA Forest Service photo.

Twig Beetles

Pityophthorus spp.
Hosts: Common or two-needle pinyon and ponderosa pine

In Arizona, ground and aerial observations in 2022 noted twig beetles and drought contributing to branch and twig flagging in ponderosa and pinyon pines, and in some cases, tree mortality in pinyon pine on the Coconino and Kaibab NFs. The majority of damage was recorded on the Coconino NF (53%), White Mountain Apache Tribal Lands (25%), and on neighboring Apache Sitgreaves NFs (10%). Prescott scale contributed to acres with ponderosa pine branch flagging in the White Mountains, although it was not recorded separately. In New Mexico, drought-stressed stands of ponderosa pine located on Mt. Taylor and the San Mateo Mountains, Cibola NF were associated with smaller areas of twig beetles killing the tips of ponderosa pine branches. Branch flagging from twig beetles was also observed on the Carson NF near Tres Piedras and on the Santa Fe NF along the eastern edge of the Sangre de Cristo Mountains. Combined with water stress from drought conditions, these areas may have accelerated mortality if drought conditions persist.

STATUS OF DISEASES



Phellinus tremulae stem decay in quaking aspen
USDA Forest Service photo

Status of Major Diseases

Mistletoes

Dwarf Mistletoes

Arceuthobium spp.
Hosts: Conifers

Dwarf mistletoes are among the most widespread and damaging forest pathogens (disease-causing organisms) in the Southwestern Region with over one-third of the ponderosa pine type (Figure 26) and up to one-half of the mixed conifer type having some level of infection. Damage to host trees from dwarf mistletoe infection includes growth reduction, deformity (especially the characteristic witches' brooms), and decreased longevity. Severely infested areas have higher tree mortality rates than uninfected areas. Weakened trees can be killed by other damaging agents such as bark beetles. Dwarf mistletoes have an ecological role, as they provide bird roosting habitat and an occasional food source for some mammals and birds. There are eight species of dwarf mistletoe in the region, each with a primary tree host. The species that primarily affect ponderosa pine, pinyon pine, and Douglas-fir are the most common and are found throughout most of their respective host ranges, while the other species have more limited distributions (Figure 27). In 2022, measurements continued on a permanent plot network established in 1991. These data will provide information on dwarf mistletoe incidence, impacts, and rate of spread. More information can be found in the "Other Entomology and Pathology Activities in 2022".

Figure 26. Witches' broom on a ponderosa pine induced by southwestern dwarf mistletoe (*Arceuthobium vaginatum* subsp. *cryptopodum*; left) and female shoots of the parasitic plant bearing seeds (right). USDA Forest Service photos.

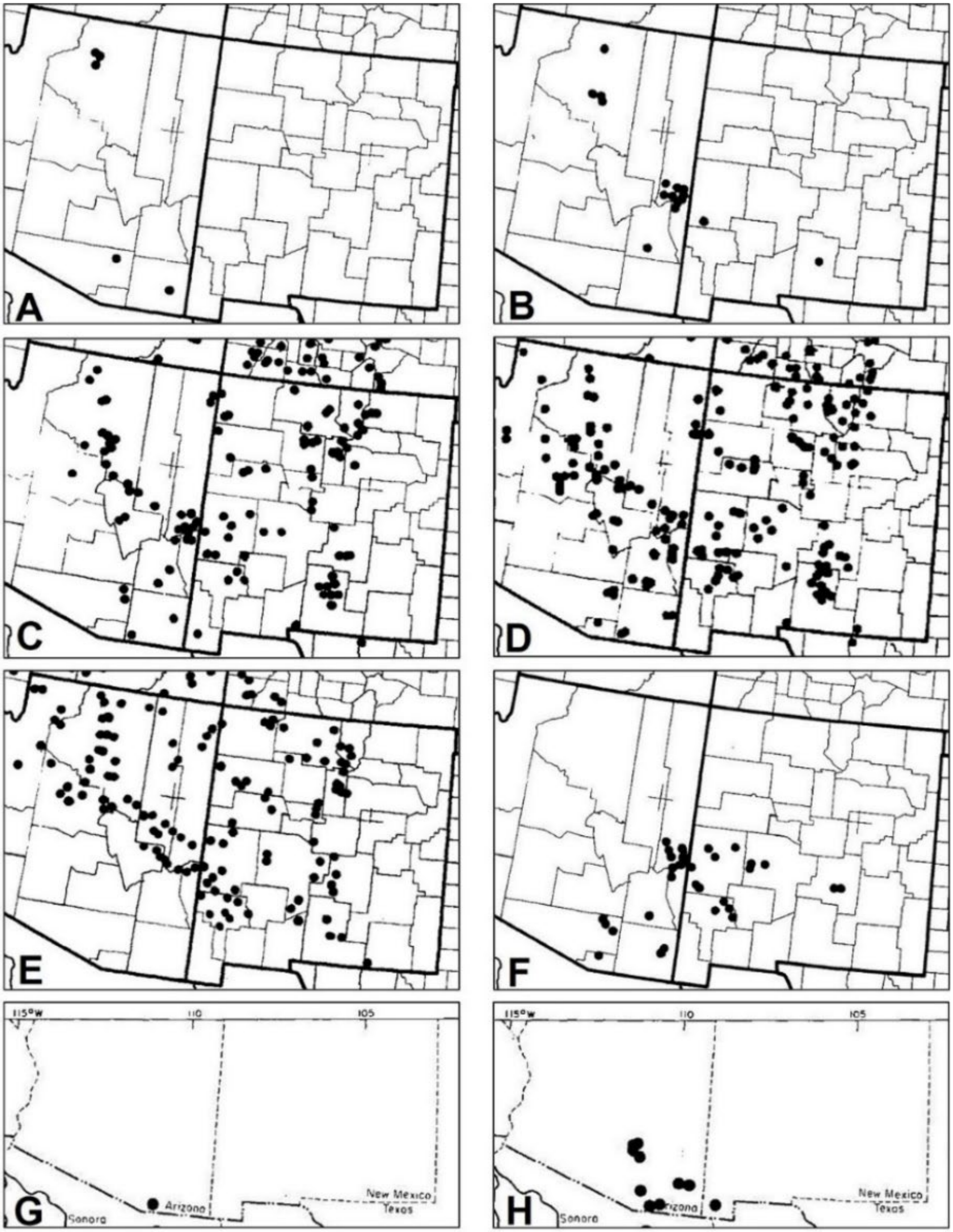


Figure 27. Distributions of dwarf mistletoe species in the Southwestern Region principally infecting white fir (A, *Arceuthobium abietinum* f. sp. *concoloris*), spruce (B, *A. macrocarpum*), Douglas-fir (C, *A. douglasii*), ponderosa pine (D, *A. vaginatum* subsp. *cryptopodum*), pinyon pine (E, *A. divaricatum*), southwestern white pine (F, *A. apachecum* and G, *A. blumeri*), and Chihuahua pine (H, *A. gillii*). Maps are adapted from Hawksworth and Wiens (1996).

True Mistletoes

Phoradendron spp.
Hosts: Junipers, Arizona cypress, white fir, and various hardwoods

Eight species of true mistletoe occur in the Southwestern Region. These mistletoes are less damaging to their hosts than dwarf mistletoes, but heavy infestations can reduce host longevity during periods of drought. The leafless *Phoradendron juniperinum* on junipers is probably the most widespread and abundant species. Big leaf mistletoe (*P. macrophyllum*) is ubiquitous throughout many riparian areas in the region where it infects most riparian hardwood species (excluding oaks). Southwestern oak mistletoe (*P. coryae*) is common on oaks in lower elevations and in southern portions of the region. Desert mistletoe (*P. californicum*), another leafless species, can be abundant on mesquite and palo verde in desert woodlands. There is one true mistletoe known to infect white fir (*P. pauciflorum*), which is limited to southern Arizona. *Phoradendron densum* is also common in Arizona cypress around Sedona.

Root Diseases

Root diseases are common in forests of the Southwestern Region. They can predispose trees to root failure, a concern in campgrounds and other developed recreation areas. In the Southwest, root diseases affect a wide range of hosts but are more common in mixed conifer and spruce-fir forests than in ponderosa pine. Root disease can also be found in hardwood species. Root diseases spread slowly, so overall extent changes little from year to year. Root disease is often described as a “disease of the site” as it can persist in the soil as a saprophyte on stumps and large roots for decades after host trees are removed or killed by fire.

Armillaria Root Disease

Armillaria spp.
Hosts: Spruce, true firs, Douglas-fir, ponderosa and pinyon pines, oaks, and occasionally aspen

Armillaria root rot is the most common root disease in the Southwest, where it is estimated to account for up to 80% of all root disease-associated mortality (Figure 28). Although all conifer species and size classes can be infected, root disease is more common in old growth mixed conifer and spruce-fir forests. *Armillaria solidipes* (=*A. ostoyae*) is the major *Armillaria* species in southwestern coniferous forests. *Armillaria gallica* has also been identified in mixed conifer forests in Arizona but is typically considered a saprophyte of dead trees. In addition, *A. mellea* has been found in live oaks in southern Arizona. Previous surveys in mixed conifer forests on the North Kaibab RD, Kaibab NF found *Armillaria* spp. on about 30% of standing live trees.

Figure 28. Signs of Armillaria root disease: mycelial fans may be found underneath the bark at the base of infected trees (left); fruiting bodies are tan colored, gilled mushrooms which are sporadically produced singly or in clusters on or near infested trees (center); and root-like rhizomorphs are often found growing along diseased roots or through the soil (right). USDA Forest Service photos.

Heterobasidion Root Disease (Formerly Annosus Root Disease)

Heterobasidion irregulare and *H. occidentale*

Hosts: Ponderosa pine (*H. irregulare*), true firs and Engelmann spruce (*H. occidentale*)

Heterobasidion root disease is the second most common root disease in the Southwest, where it is found in higher elevation ponderosa pine and mixed conifer forests throughout Arizona and New Mexico. Fruiting bodies are commonly found inside hollow stumps and sometimes on downed logs and upturned roots. *Heterobasidion occidentale* is common in white fir in the Southwest but also occurs on subalpine fir and Engelmann spruce. *Heterobasidion irregulare* affects ponderosa pine and is found throughout the region. It does not commonly cause disease in the Southwest, though. Like *Armillaria* spp., *Heterobasidion* spp. are known as saprophytes or nutrient recyclers of dead woody material as well as pathogens and may persist on a site even in the absence of live hosts.

Other Common Root Diseases

Other common root diseases in the Southwest include Schweinitzii root and butt rot, caused by the fungus *Phaeolus schweinitzii*, which is often found on older Douglas-fir and occasionally on ponderosa pine, southwestern white pine, white fir, and spruce (Figure 29). Tomentosus root disease, caused by *Onnia tomentosa*, is found on spruce and Douglas-fir and can be a major hazard tree consideration where it occurs in developed recreation sites. Black stain root disease, caused by *Leptographium wageneri*, appears to be rare in the Southwest but has been reported in pinyon pine in northern New Mexico and Douglas-fir on Mescalero Apache Tribal Lands. Ganoderma root rot is caused by two species of *Ganoderma*, *G. applanatum* and *G.lucidum. Ganoderma applanatum* is the primary root disease affecting aspen in the Southwest. The disease causes crown dieback, windthrow, and mortality, especially in older aspen stands (though aspen of all ages are affected). Aspen stands on mesic sites seem to have higher incidence of disease compared to drier sites. *Ganoderma lucidum* affects many hardwood species, including Fremont cottonwood, Emory and silverleaf oak, Arizona sycamore, and netleaf hackberry. Infection may lead to gradual decline, and the presence of a fruiting body indicates high potential for failure.

Figure 29. *Phaeolus schweinitzii* fruiting body growing near an infected tree and incorporating various plants and debris from the forest floor (left) and associated brown rot in an infected stump (right). USDA Forest Service photos.

Stem Decays

Stem decays are common in older trees throughout the Southwestern Region. Decay represents an economic loss in terms of timber production and can increase hazards on developed sites, but decayed trees also provide important cavity habitat for many wildlife species, especially birds. One of the most common stem decays causing brown rot in the Southwest is red belt fungus, *Fomitopsis schrenkii*, which affects conifers and sometimes aspen. Prominent stem decays causing white rots in the region include red rot, *Dichomitus squalens*, of ponderosa and pinyon pines; red ring rot, *Porodaedalea pini*, affecting most conifers; Indian paint fungus, *Echinodontium tinctorium*, on true fir and occasionally Douglas-fir or spruce; false tinder conk, *Phellinus tremulae*, on aspen; pouch fungus, *Cryptoporus volvatus*, a sap rot found on bark beetle-killed conifers; *Phellinus everhartii* and *Inonotus dryophilus* on oak species; *Inonotus munzii* on cottonwoods; and *Phellinus weirianus* on Arizona walnut.

Stem Rusts

White Pine Blister Rust

Cronartium ribicola
Hosts: Southwestern white, limber, and Rocky Mountain bristlecone pines (aecial stage); *Ribes*, *Castilleja*, and *Pedicularis* spp. (telial stage)

White pine blister rust (WPBR), caused by *Cronartium ribicola*, is the only known exotic invasive forest disease in the Southwestern Region(Figure 30), where thousands of acres of mesic mixed conifer forest have severe WPBR infection (more xeric sites generally have low to moderate infection). Top kill is very common in severely affected areas. Although Rocky Mountain bristlecone pine is susceptible, WPBR has not yet affected this species within the region.

Figure 30. Branch flagging on a southwestern white pine due to girdling by white pine blister rust infections (left), rodent stripping of cambium on an infected stem (center), and blisters on a branch bearing sacs of aeciospores (right). USDA Forest Service photos.

In New Mexico, this disease continues to cause heavy damage to southwestern white pines on the Sacramento Mountains, where the disease has likely been established for over 40 years (Figure 31). Based on a set of representative monitoring plots, roughly 45% of the white pines in this area, which includes Mescalero Apache Tribal Lands and most of the Lincoln NF, are infected. White pine blister rust also occurs on the Gila, Cibola, and Santa Fe NFs of New Mexico. In 2022, WPBR infection on the Black Range of the Gila NF was confirmed, and the disease is now found on most mountain ranges in central and southern New Mexico.

In Arizona, WPBR was first detected in 2009 on White Mountain Apache Tribal Lands and neighboring Apache-Sitgreaves NFs, which are still the only land management units known to be affected in this state (Figure 31). Age estimation of older cankers suggest the WPBR pathogen may have been present for 20 years but at undetectable levels. Since 2009, favorable weather conditions for the pathogen have allowed for continued disease expansion into new areas, including into more moderate hazard sites throughout most of the White Mountains. However, WPBR is still absent throughout much of the host type in Arizona.

In collaboration with Northern Arizona University, permanent monitoring plots have been established throughout the host type in the region. Several strategies to conserve genetic resistance against WPBR are being implemented. More information can be found in the "Other Entomology and Pathology Activities in 2022" section of this document under "White Pine Blister Rust Genetic Resistance".

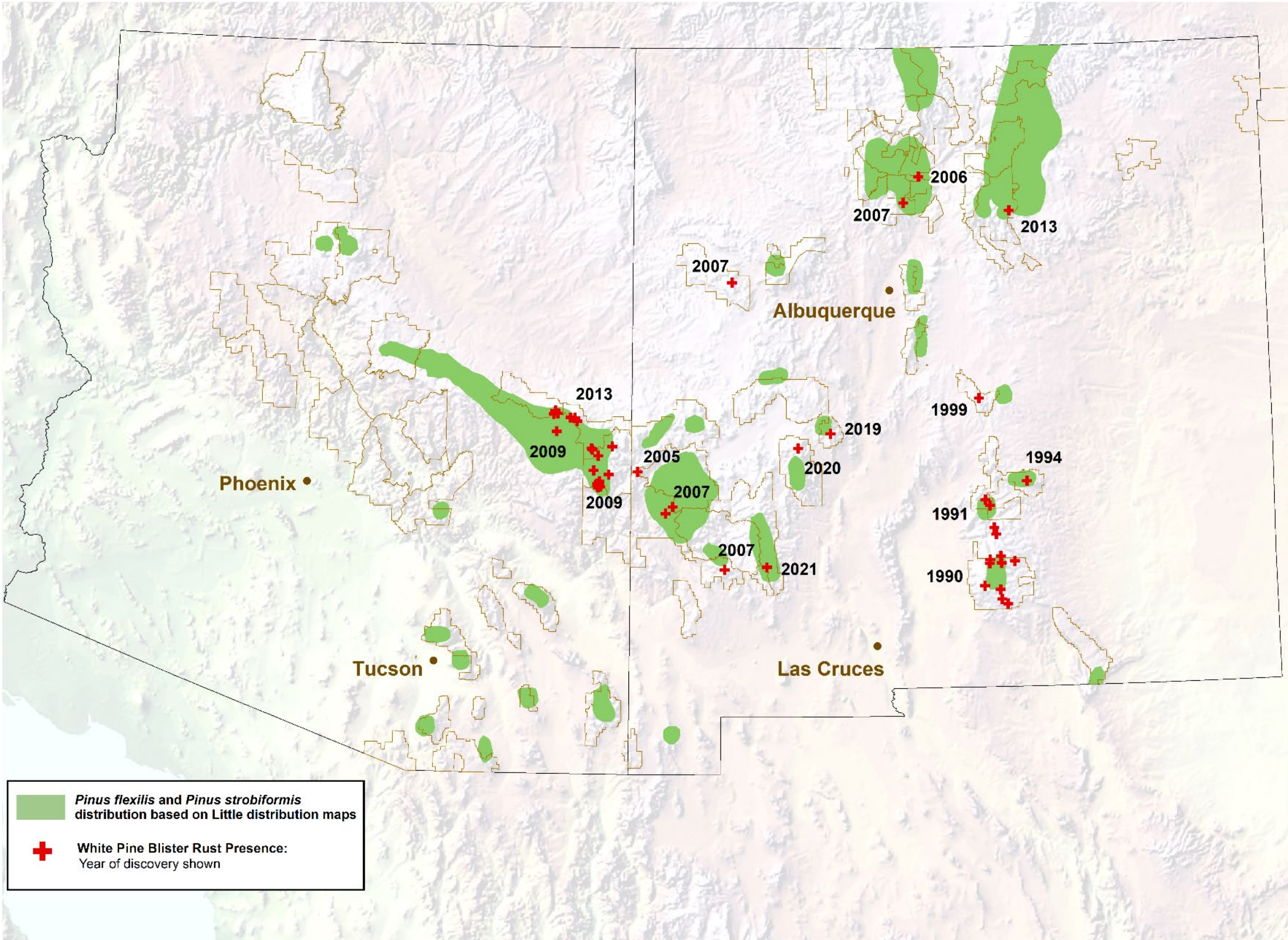


Figure 31. Distribution of known white pine blister rust infection centers within the Southwestern Region and the year in which they were discovered. USDA Forest Service image.

Broom Rusts

Melampsorella caryophyllacearum
Hosts: True firs (aecial stage) and chickweed (telial stage)
Chrysomyxa arctostaphyli
Hosts: Spruce (aecial stage) and bearberry or kinnikinnick (telial stage)

There are two species of broom rust that occur at relatively low levels on their respective hosts in the Southwestern Region (Figure 32). However, higher infestations of fir broom rust occur on the Sandia and Manzano Mountains of central New Mexico and a few other locations. Damage from this easily recognized disease has not been well quantified, but infection can result in top-kill, especially in spruce. Falling brooms or stem breakage may present a hazard in developed recreation sites.

Figure 32. Witches' broom associated with fir broom rust on a white fir bole (left) and spruce broom rust aecial spore sacks on needles from within a witches' broom on an Engelmann spruce (right). USDA Forest Service photos.

Limb Rust and Western Gall Rust

Cronartium arizonicum and *Endocronartium harknessii*, respectively
Hosts: Ponderosa pine (aecial stage) and *Castilleja* spp. (telial stage, *C. arizonicum* only)

There are two rust diseases on ponderosa pine in the Southwestern Region. The most frequently observed is *Cronartium arizonicum*, the cause of limb rust. Limb rust is common in portions of Arizona and can be quite damaging to individual trees. Limb rust incidence in New Mexico is infrequent but has been found on Jicarilla Apache Tribal Lands. The fungus causes orange-colored pustules on dying branches with progressive upward and downward branch mortality, generally initiating from the center of the crown. Waves of new infection are initiated by climate conditions conducive to this disease and may occur at intervals of several years.

Western gall rust, caused by *Endocronartium harknessii*, deforms but seldom kills older trees. Infection typically causes the growth of large galls on infected branches. Occasionally, during wave infection years, this pathogen has caused mortality in seedlings and saplings. The pathogen that causes this rust disease does not have an alternate host, and infection proceeds from pine to pine. This disease is uncommon in the Southwestern Region.

Canker Fungi

Canker diseases are commonly associated with damaged or stressed trees. Disturbances which may inflict mechanical damage to trees or stressors such as drought can increase the incidence of canker diseases. These pathogens are often involved in aspen mortality and dieback due to the soft living tissue of the bark, which makes aspen extremely susceptible to wounding and subsequent infection. Sooty bark canker, caused by *Encoelia pruinosa*, is the most lethal canker of aspen, while Cytospora canker, caused by *Cytospora* spp., is the most common. *Valsa melanodiscus* (anamorph *Cytospora umbrina*) causes alder heat canker, which continued to be observed in association with dieback and mortality of Arizona alder (*Alnus oblongifolia*) in Oak Creek Canyon in 2022. Alder heat canker has also been associated with large scale dieback and mortality of alder in Alaska, Colorado, and New Mexico.

In 2022, pathogens in the genus *Biscogniauxia* continued to be observed causing dieback and mortality of Emory and silverleaf oaks in Arizona, primarily on the Nogales, Douglas, and Safford RDs, Coronado NF (Figure 33). The most severe dieback and mortality associated with these pathogens thus far has been observed in Madera Canyon in the Santa Rita Mountains and along Turkey Creek in the Chiricahua Mountains of southeastern Arizona. Mortality is distributed across size classes, including sapling-sized trees. In 2022, *Biscogniauxia* spp. were observed on dead oaks on the Silver City and Reserve RDs, Gila NF. This represents the first report of these pathogens in New Mexico. Prior to 2018, there had been no reports of *Biscogniauxia* spp. affecting oaks in Arizona or New Mexico. Two species have been identified, *Biscogniauxia mediterranea* and a previously undescribed *Biscogniauxia* species. A first report formally documenting *Biscogniauxia mediterranea* causing disease on Emory oak was published in 2021 (Wright et al. 2021). Pathogens of this genus are generally associated with dieback and mortality of drought-stressed trees. As conditions in the Southwest continue to become hotter and drier, it is likely these pathogens will continue to become more prevalent on the landscape.

Figure 33. *Biscogniauxia* spp. fruiting bodies emerging from thin bark of sapling in Madera Canyon, Arizona, note the dark black and light grey color of the fruiting body (left); light grey fruiting bodies emerging from cankers on silverleaf oak near Turkey Creek, Chiricahua Mountains, Arizona (center); and large canker and emerging fruiting body on Emory oak in Madera Canyon (right). USDA Forest Service photos.

Foliar Diseases

Foliar diseases in the Southwest may occur in conifers (needle casts) or hardwoods. Fungal species causing these diseases may overwinter in old leaf litter from the previous year or in previously infected foliage that has not been cast. Outbreaks are sporadic and highly dependent on favorable weather conditions, generally coinciding with above average moisture in the spring and/or early summer. In conifers, symptoms may be similar to winter injury or salt damage, but the presence of fruiting bodies on needles can allow for confirmation of needle cast disease. Fruiting bodies are typically black in color but can be tan or brown. Foliar diseases in hardwoods are most often observed in aspen, cottonwood, willow, and sycamore. Heavy infections may cause defoliation, particularly in the lower crowns where humidity tends to be higher. Although occasional outbreaks can appear quite dramatic, foliar diseases rarely cause long-term damage in the region.

In New Mexico, no major damage by foliar pathogens was observed via aerial survey in 2022. However, Melampsora rust on aspen and powdery mildew on Gambel oak were both observed to be widespread along Alamitos Creek in the Sangre de Cristos (Carson NF) during a ground check. *Lophodermella arcuata* was also found nearby infecting a few small limber pines along the Rio Pueblo in Agua Piedra Campground during another ground check.

In Arizona, chronic white pine needle cast caused by *L. arcuata* has been observed impacting southwestern white pine on the San Francisco Peaks and is particularly severe at higher elevations where conditions are more conducive to this pathogen (Figure 34). In addition, sycamore anthracnose (A*piognomonia veneta*) continues to affect several riparian areas throughout Arizona. This foliar disease is particularly noticeable in Oak Creek Canyon and Wet Beaver Creek near Sedona where the infection appears to be a chronic issue. In 2022, damage was mapped on about 110 acres on the Apache-Sitgreaves NFs and State and Private Lands.

Figure 34. Southwestern white pine exhibiting red crown discoloration due to *Lophodermella arcuata* infection on the Coconino National Forest in Arizona. Note the dark green ponderosa pine which are not susceptible to this disease. USDA Forest Service photo.

Abiotic Damage

Salt

De-icing salt use has contributed to continued ponderosa pine damage along highways in the Southwestern Region (Table 4). Approximately 620 acres with salt damage were reported in 2022, increasing from 520 acres in 2021. About 480 acres with damage were mapped in Arizona and 130 acres were mapped in New Mexico. Damage has typically been observed along major corridors, including county and city roadways, as municipalities continue use of de-icing salts. Application of dust abatement salt is also associated with damage to ponderosa pine along dirt roads in rural housing areas.

Red Belt Winter Injury

Late season winter injury can inflict significant damage to affected trees. In New Mexico, a 6,480-acre red belt event was recorded in 2021 with discoloration found on a variety of conifer species of different age and size, including ponderosa pine, Douglas-fir, and white fir. About 85% of this damage occurred on the Lincoln NF with the remainder found on Mescalero Apache Tribal Lands and State and Private lands. The red belt event was apparent from south of Sierra Blanca north throughout the Smokey Bear RD and included a large area of the Capitan Mountains. Red belt is a landscape-scale winter injury event that occurs with the sudden appearance of warm dry winds (e.g., Chinook winds) producing a temperature inversion. A relatively thin layer of warm air arrives that cannot mix downward and continues to contact side slopes. Trees exposed to unseasonably warm air by day receive seasonably cold air at night. This alteration of warm and cold air exposure, along with the frozen condition of the soil, results in desiccation injury because daytime transpiration removes moisture from the needles more rapidly than roots in frozen soil can replace it. Although most affected trees were expected to recover, damage was still apparent across about 910 acres during 2022 aerial detection surveys with widespread mortality in these areas. No new areas of damage were recorded.

Wind

A major windthrow event occurred during the 2021-2022 winter and affected about 10,300 acres in New Mexico on the Sangre de Cristo Mountains. Damage was primarily recorded on the Carson NF (57.1%), state and private lands (27.4%), and Taos Pueblo tribal lands (15.2%). Much of this windthrow event occurred in spruce-fir stands, and these areas will be monitored over the next few years for elevated levels of spruce beetle infestation. As downed trees are infested, beetles may subsequently colonize nearby, currently undamaged stands.

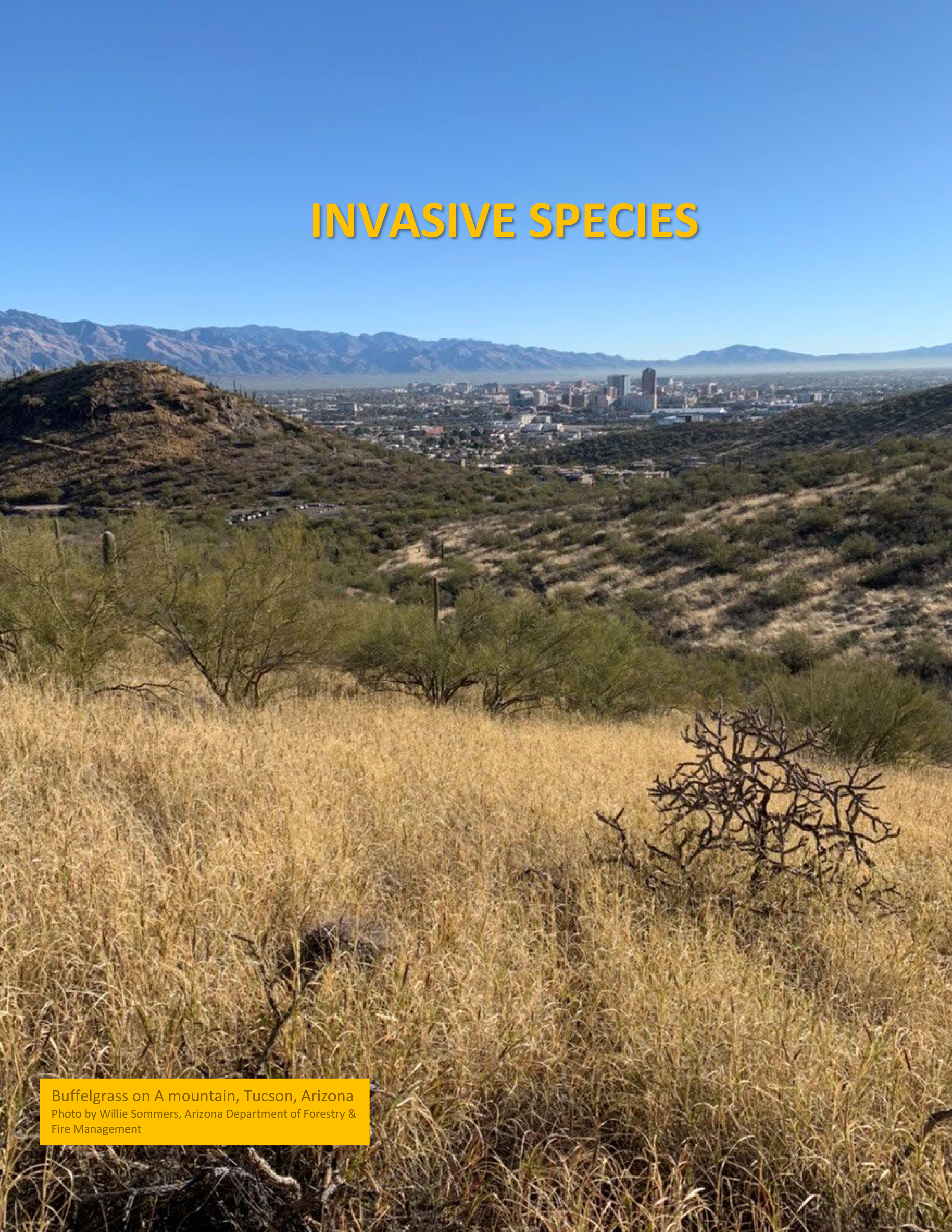
Drought

The Southwestern Region experienced exceptional drought conditions entering 2022. Evidence of this acute stress was observed to some extent in all tree species but was particularly severe in pinyon-juniper woodlands (Figure 35) and ponderosa pine (Table 4). Large areas of juniper crown dieback across Arizona were mapped in 2022 on 98,850 acres across multiple ownerships, a reduction from the 334,100 acres recorded in 2021 (Table 4). No significant juniper dieback was mapped in New Mexico in 2022 after 23,720 acres with damage were reported in 2021, mostly around the Guadalupe Mountains, Lincoln NF (90%).

Drought-stressed ponderosa pine exhibited slight yellowing of needles and some premature needle loss. Symptoms were most evident on dry ridges and upper slopes. New Mexico accounted for most of the drought stress mapped in ponderosa pine with 74,470 acres in 2022 compared to 121,360 acres in 2021 (Table 4). Most of this was mapped on Carson NF (28,950 acres), State and Private lands (16,740 acres), Santa Fe NF (10,680 acres), and Gila NF (7,520 acres). In Arizona, acres of ponderosa pine drought impacts decreased from 18,720 acres in 2021 to 610 acres in 2022. Most of the damage was mapped on Navajo Nation Tribal Lands. In contrast, drought stress affecting other species rose from 48,950 acres in 2021 to 96,440 acres in 2022. Most of this damage was mapped on the Coconino (48,000 acres), Kaibab (18,970 acres), and Tonto NFs (10,640 acres). Delayed, late season mortality associated with drought stress can be high, and normal ADS flights may underestimate mortality in years of acute drought. Drought stress may increase susceptibility to insects and diseases which do not affect vigorous trees. Drought may also act as a principal mortality agent in some cases.

Figure 35. Widespread drought-related juniper dieback on Wupatki National Monument, an ongoing and severe issue in Arizona. USDA Forest Service photo.

INVASIVE SPECIES



Buffelgrass on A mountain, Tucson, Arizona
Photo by Willie Sommers, Arizona Department of Forestry & Fire Management

Invasive Species

Invasive species and diseases have increasingly become a greater threat throughout the Southwestern Region. Invasive species means, with regard to a particular ecosystem, a non-native organism whose introduction causes or is likely to cause economic or environmental harm, or harm to human, animal, or plant health (from Executive Order 13112, as amended – Safeguarding the Nation from the Impacts of Invasive Species, 2016). The Executive Order requires Federal agencies to prevent and control these species and to minimize their economic, ecological, and human health impacts. Invasive insects and diseases are covered in the entomology, pathology, and in the special projects section while mainly invasive plants are covered here.

Table 5 shows some of the major invasive species and diseases that pose the greatest threats to terrestrial and aquatic ecosystems on national forests and grasslands in the Southwestern Region. Many other invasive or exotic species (e.g., introduced fish species) also can seriously impact native species. Further information on invasive species associated with national forests and grasslands in the Southwestern Region may be found at http://www.fs.usda.gov/main/r3/forest-grasslandhealth/invasivespecies.

Table 5. Major invasive species and diseases threatening national forests and grasslands in Arizona and in New Mexico.

Type	Common name, Species	Impacts
Pathogens	Chronic wasting disease, prion-based Chytrid fungus, *Batrachochytrium dendrobatidis* Whirling disease, *Myxobolus cerebralis* White pine blister rust, *Cronartium ribicola*	Deer and elk Amphibians Salmonid fish species Five needle pines
Terrestrial Plants	Buffelgrass, *Cenchrus ciliaris* Cheatgrass, *Bromus tectorum* Giant cane, *Arundo donax* Musk thistle, *Carduus nutans* Yellow bluestem, *Bothriochloa ischaemum*	Desert plant communities Grasslands and shrublands Waterways Grasslands and shrublands Grasslands and shrublands
Invertebrates	Northern crayfish, *Orconectes virilis* Spruce aphid, *Elatobium abietum* Oystershell scale, *Lepidosaphes ulmi* Quagga mussel, *Dreissena rostriformis bugensis*	Aquatic plants and animals Engelmann and blue spruce Aspen and other hardwoods Streams, rivers, and lakes
Vertebrates	American bullfrog, *Lithobates catesbeiana* Feral hog, *Sus scrofa*	Aquatic animals Plant communities and small animals

Buffelgrass

Buffelgrass (*Cenchrus ciliaris*) is the single greatest invasive threat to the Sonoran Desert in the Southwestern Region (Figure 40). This bunchgrass was originally introduced from Africa into the southwestern U.S. as a forage grass and has since spread into the Sonoran Desert. Buffelgrass out-competes native desert vegetation for water, nutrients, and sunlight. The grass also forms a dense, continuous fine fuel that promulgates wildfire, leading to more widespread and intense fires. Plant species native to the Sonoran Desert, such as saguaro cactus (*Carnegiea gigantea*) and palo verde (*Parkinsonia microphylla*), are not adapted to fire and are generally extirpated after several fire cycles.

The Coronado NF and other land management agencies in Arizona are currently engaged in intensive management projects to detect and control buffelgrass on a landscape scale. The Sonoran Desert Museum coordinates efforts by local federal agencies, state agencies, and private organizations in the fight against buffelgrass.

Yellow Bluestem

Yellow bluestem (*Bothriochloa ischaemum*) is a warm-season perennial bunchgrass that is commonly found along many road systems in the Southwestern Region. The panicle of yellow bluestem has a fan or finger-like appearance, and the stem has a pale-yellow stem color below the nodes that transitions into green (Figure 36). This bunchgrass species was originally imported from Eurasia and northern Africa in the early 1900s for erosion control and as a forage crop for haying and grazing. Yellow bluestem is very adaptable and highly aggressive, especially in disturbed areas. It can form a monoculture that lowers biodiversity of native plant communities by reducing abundance, diversity, and richness of native plant species. Infestations of yellow bluestem also alter soil carbon: nitrogen ratios and the composition of soil microbial communities, including arbuscular mycorrhizae. This transformation in soil properties can inhibit growth of native plant species. In addition, yellow bluestem-infested areas can be relatively unsuitable for nesting, brood rearing, or year-round habitat for grassland bird species. The lower bird numbers may reflect decline in arthropod abundance and/or biomass.
Yellow bluestem has become invasive in native grasslands and pastures in the Midwest, southcentral Arizona, and the southern Great Plains (Oklahoma, Texas, and eastern New Mexico).

The species is currently listed on Arizona's noxious weed list but has not been listed by New Mexico. Yellow bluestem is practically impossible to eradicate once established. Control becomes progressively more difficult and expensive the longer yellow bluestem is allowed to grow and spread. Only non-selective herbicides (glyphosate and imazapyr) are available for yellow bluestem control if manual removal or tillage is not an option. It is therefore necessary to eradicate or contain new populations when possible; otherwise, intensive management measures will eventually be needed to adequately control the species.

Figure 36. Yellow bluestem near Algin, Arizona. Borderlands Restoration Network photo.

Saltcedar

One of the most widely distributed invasive species in the Southwestern Region is saltcedar (*Tamarix* spp.), which occurs as a shrub or tree along many waterways and riparian areas. In 2001, several species of the tamarisk leaf beetle (TLB) (*Diorhabda* spp.) from central Eurasia were released in western states as a host-specific biocontrol agent. Adult TLB and larvae both consume saltcedar foliage, which can damage or kill the plant over several years. Feeding by the beetle causes saltcedar leaves to dry out and turn brown while remaining on the stem (Figure 37); thus, crown discoloration is commonly seen in affected saltcedar stands.

Figure 37. Tamarisk leaf beetle. USDA Forest Service photo by Camden Bruner.

Since their release, different species of TLB have migrated throughout much of Arizona and New Mexico. Further information on the TLB may be found at the website of RiversEdge West (formerly, the Tamarisk Coalition) at https://www.riversedgewest.org.

Areas with defoliated saltcedar may become infested by other invasive weeds that need to be controlled. In addition, the advancing migration of tamarisk leaf beetle species threatens nesting habitat used by the Federally listed southwestern willow flycatcher (*Empidonax traillii extimus*), which nests in saltcedar-dominated plant communities that have replaced native willow species (*Salix* spp.).

In 2022, aerial surveys detected tamarisk leaf beetle-caused defoliation on 6,760 acres in Arizona. Most (74%) of the damage was detected on state and private lands. Nearly 19% of the damage was observed on tribal lands, especially the advancing front in central Arizona which effects the Tonto NF and San Carlos Apache Tribal Lands along the Salt River and White Mountain Apache Tribal Lands along Cibeque and Carrizo Creek.

Figure 38. Insect and disease training on the Apache-Sitgreaves NF. USDA Forest Service photo.

Other Entomology and Pathology Activities in 2022

Forest Health Regional Training

The FHP staff provides annual training opportunities to resource managers on insect and disease identification, effects, and management as well as hazard tree identification and mitigation. In 2022, due to the COVID-19 pandemic, these trainings were held virtually. Presentations were given live via Microsoft Teams, and attendance was at an all-time high and included multiple agencies and diverse stakeholders. Presentations were also recorded and made available to internal and external partners. Follow-up field days occurred in New Mexico on Mescalero Apache tribal lands and Lincoln NF and in Arizona, on the Apache-Sitgreaves NFs for FS, BIA, and White Mountain Apache tribal personnel (Figure 38). Additional field trainings were provided in Arizona to Grand Canyon NP and Ecological Restoration Institute staff. Typically, regional trainings occur annually with the location alternating between Arizona and New Mexico. Another virtual regional training is being planned for 2023, followed by field days in each respective FHP zone.

Dwarf Mistletoe Plot Re-Measure

The Pest Trend Impact Plot System (PTIPS), focused largely on southwestern dwarf mistletoe (SWDM), was established in 1991 and has been re-measured on roughly 10-year intervals. The fourth re-measure of the plot network was initiated in 2017 in Arizona and 2020 in New Mexico. The PTIPS plots in Arizona were completed in 2020. This long-term plot system was established to assess rate of SWDM spread, as well as impacts on growth and survival of ponderosa pine infected by the pathogen. Data are being collected on tree status (live or dead), severity of infection, height, diameter, presence of regeneration, and presence of other pathogens or insects which may impact the health of the tree. These data, along with data from a plot network monitoring effects of fire on SWDM, will be used to develop new parameters for the dwarf mistletoe model in Forest Vegetation Simulator and serve as the basis for updated management guidelines for the region. *For more information, contact Gregory Reynolds or Nicholas Wilhelmi.*

White Pine Blister Rust Genetic Resistance

In 2022, FHP continued work to sustain southwestern white pine and limber pine in the face of the introduced pathogen *Cronartium ribicola*, the causal agent of white pine blister rust. This work is being conducted in collaboration with Dr. Kristen Waring of Northern Arizona University, Dr. Owen Burney of New Mexico State University, Dr. Richard Sniezko of the Dorena Genetic Resource Center (DGRC), and others. Seeds were collected from parent trees across the range of southwestern white pine to grow and test for resistance to white pine blister rust and assess adaptive traits. Progeny of these parent trees were inoculated with *Cronartium ribicola* at DGRC in Cottage Grove, OR to evaluate resistance. A small percentage (around 5%) of trees have shown resistance in these trials with locations of parent trees distributed across much of the Region. Two field trials have been established in cooperation with the Mescalero Apache Tribe (2017) in New Mexico and the Apache-Sitgreaves National Forests (2018) in Arizona. These are long-term, fenced test sites that will be used to evaluate the durability of various disease resistance mechanisms observed at DRGC. Additional plantings to replace killed seedlings and increase diversity of genotypes being tested on the sites will occur in future years with potential for expansion into new plantings in heavily thinned rec sites. In addition, FHP has collected scion from parent trees throughout the region over the last several years which have shown some level of resistance to white pine blister rust, either via major gene resistance or quantitative resistance. No scion was collected in 2022. Overall, resistant trees have been collected from the Lincoln NF and Mescalero Apache Tribal Lands in southern New Mexico, the Zuni Mountains (Cibola NF) of northern

New Mexico, and the White Mountains of Arizona (Apache-Sitgreaves NFs). Scion material is being grafted into a seed orchard in Mora, NM and will also be used to provide disease resistant seed for future reforestation efforts. In 2022, FHP and partners at Northern Arizona Univeristy also began a ten year remeasure of an extensive permanent plot network which spans much of the Region. This plot network consists of 80 permanent monitoring plots that were randomly established between 2010-2012 in stands with more than 20ft^2 basal area per acre of white pine. Of the original 80 plots, 23 have burned in wildfire events after installation and have already been re-measured. An additional 6 are located inside a 2022 fire perimeter, leaving 51 plots for 2022 re-measurements. We were able to find and remeasure 25 of the 51 plots in 2022. The effort to complete the remeasure will continue through 2023. *For more information, contact Gregory Reynolds or Nicholas Wilhelmi.*

Fungal Diversity in Conifer Nurseries throughout the Region

Plant pathologists Greg Reynolds and Nicholas Wilhelmi (New Mexico and Arizona Zones, respectively) are collaborating with researchers John Dobbs and Jane Stewart from Colorado State University, Mee-Sook Kim from USDA Forest Service - Pacific Northwest Research Station, and others on a Special Technology Development Program-funded project to investigate diversity of *Fusarium* and *Phytophthora* species in tree nurseries throughout the west. These pathogens can cause seedling mortality in nurseries, limit success of out-planted nursery stock, and in the case of *Phytophthora* species potentially initiate devastating epidemics on the landscape if introduced in restoration plantings. Sampling throughout the region was completed in 2021 with a tribal facility and two state university facilities assessed, and sample processing and analysis was completed in 2022. The highest diversity of fusarioid fungi found in any state surveyed in this study was observed in New Mexico. *Fusarium commune, F. fujikuroi* species complex*, F. triseptatum,* and *Neocosmospora solani* were among the nursery fungal pathogen species commonly intercepted across the Southwestern Region. A peer-reviewed manuscript was prepared in 2022 summarizing these results and published in early 2023 (Dobbs et al. 2023). Future work will assess the presence of these pathogens on the landscape in restoration plantings originating from the respective sampled nursery, with funding in support of this work acquired for FY2023 via the emerging pest program. *For more information, contact Gregory Reynolds or Nicholas Wilhelmi.*

Roadside Hazard Tree Issues Following Fires

In 2022, plant pathologist Greg Reynolds and Forest Health Specialist John Formby collected data along forest roadways impacted by the Hermit's Peak / Calf Canyon Fire, the largest recorded wildfire in New Mexico history. Areas that burned with moderate or severe intensity according to Rapid Assessment of Vegetation Condition After Wildfire (RAVG) data were overlayed with priority Carson and Santa Fe NF roads to generate a map product that was subsequently used to project acres needing immediate hazard tree treatment with emergency funds. Plots installed along these roads indicated that severely burned areas could be correctly predicted with 80% accuracy using this method. Most trees in severely burned areas were already clearly dead or highly likely to die within three years due to their injuries. Assessing percent live crown was unnecessary in many of these plots due to complete crown consumption (e.g., no needles remaining at all, living or dead; Figure 39). Adjusting the data for errors and calculating survival based on the true rather than predicted burn severity in each plot resulted in only 5.9% survival for severely burned areas, and these areas were selected for initial, immediate hazard tree mitigation. Areas dominated by ponderosa pine that burned with moderate intensity had high survival with little additional mortality predicted in the next three years, allowing for a longer hazard tree treatment schedule. Plots established on the 2016 Doghead Fire in the Manzano Mountains, Cibola NF have been assessed annually since the fire to determine fall rate of fire-killed snags over time, and nearly all the killed trees fell within the first four years, demonstrating the importance of post-fire roadside hazard tree mitigation. *For more information, contact Gregory Reynolds.*

Figure 39. Severely burned stands in the Hermit's Peak/Calf Canyon footprint on the Santa Fe National Forest, New Mexico. USDA Forest Service photos.

Assessing Potential for Spruce Beetle Outbreak Following Aphid Defoliation

In 2020, AZ Zone entomologists, in collaboration with scientists from Rocky Mountain Research Station partners in Flagstaff, AZ, Logan, UT, and Bozeman, MT and faculty at Northern Arizona University, received funding from Evaluation Monitoring (EM) to assess the impact of spruce aphid defoliation on the performance of spruce beetles. The study consisted of an individual tree study to monitor how well beetles perform in spruce with different levels of aphid-caused defoliation and a network of plots stratified by defoliation levels as determined by aerial surveys. For the individual tree study, we baited thirty trees with a range of recent defoliation severities with a pheromone lure to incite spruce beetle attacks. These trees were monitored over the summer and in the fall. We evaluated beetle success by examining each tree for the presence of successful galleries and presence of larvae or pupae. Defense characteristics, in the form of terpene concentration, resin volume and resin ducts, were also analyzed for each tree. Tree mortality 18 months after baiting was higher for trees with high defoliation than trees with medium defoliation or low defoliation but was attributed to defoliation and root rot more than bark beetles. Mean resin duct density over 2021-22 was about two-fold greater for trees with medium or high defoliation compared with low defoliation. Phloem concentration of total terpenes and each of 34 constituent terpenes was similar among defoliation classes. Five months after baiting, an average of 67% of pitch tubes had beetle galleries, but this percentage did not differ over defoliation classes. The percentage of pitch tubes with larvae was lower than for galleries and differed among defoliation classes. Larvae were completely absent in trees with low defoliation, scarce in trees with moderate defoliation (6%), and most common in trees with high defoliation (20%). Results of this study suggest that spruce bark beetle under endemic conditions do not gain a reproductive advantage from trees defoliated by spruce aphid and beetle outbreaks likely do not initiate from aphid defoliation events. For the plot level data, we completed data collection in the summer of 2022, and analysis of these data are in progress. *For more information, contact Monica Gaylord.*

Pinyon Ips Phenology

Pinyon pine is a major component of woodland ecosystems and many wildland-urban interfaces in the Southwestern United States. These woodlands are important for wildlife habitat, ranching, firewood, and cultural practices to many Native American tribes. Presently, woodlands in many areas are more densely populated than they were prior to Euro-American settlement. High density woodlands can increase tree stress, particularly in times of drought. Following a period of drought in 2002-2004 mortality of pinyons was extensive and many of the trees were attacked by pinyon ips. For most of 2020 and into summer of 2021, the Southwestern Region experienced severe drought conditions and an increase in pinyon pine mortality has since been observed. The interacting roles of drought, temperature and insects are not well-understood in pinyon mortality. Pinyon ips life history, including number of generations per year, is only loosely known. Beginning in 2022, with the collaboration of Barbara Bentz, Matt Hansen, and Jim Vandygriff (Rocky Mountain Research Station, Logan, Utah) studies were undertaken to study pinyon ips phenology and describe key events in its life cycle. Forest Health Protection entomologists in both Arizona and New Mexico began to study ips phenology by deploying passive and emergence traps while recording bark beetle attacks on selected trees that were baited with lures and instrumented with temperature probes. Air and phloem temperatures will be measured and correlated with important beetle life cycle events. Lab studies conducted over winter in Logan, UT were carried out by rearing field collected pinyon ips in phloem sandwiches at a range of constant temperatures from egg to adult. A basic phenology model will be parameterized using field and laboratory data. The study will continue in Arizona and New Mexico in 2023. *For more information contact Monica Gaylord or Steven Souder.*

Developing Integrated Pest Management Strategies for Aspen Infested with Invasive Oystershell Scale

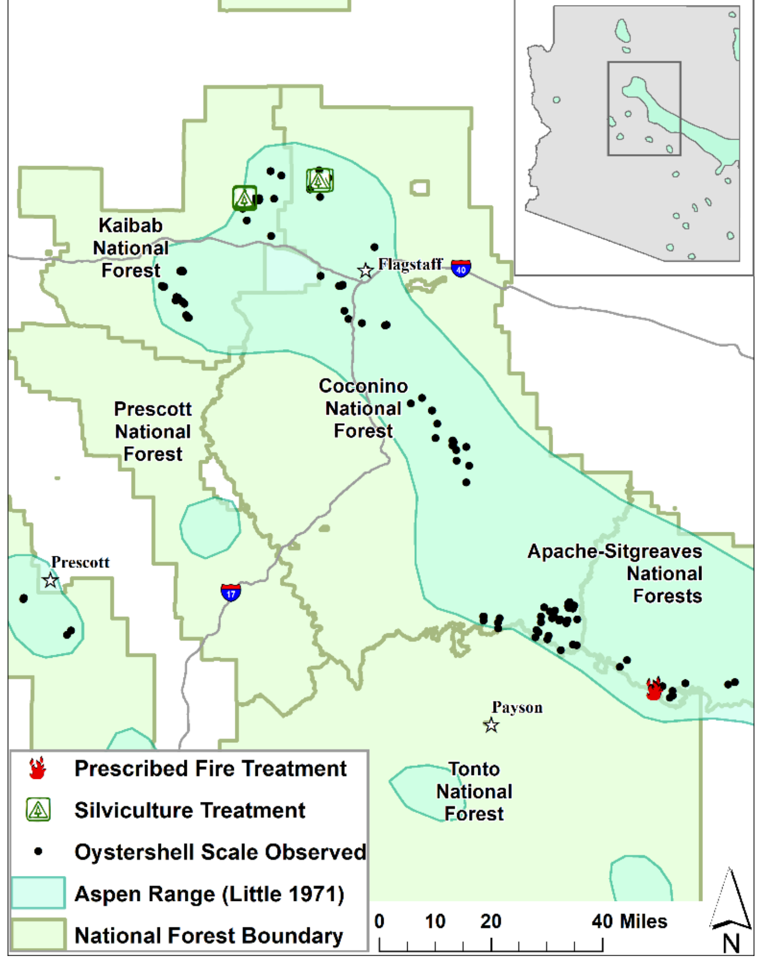


Figure 40. Map of oystershell scale extent and locations of experimental treatments to mitigate damage in aspen exclosures.

Aspen decline and mortality is severe and persistent in the hot dry Southwest, where aspen occurs near the southern limit of its range. Several factors like climate warming, prolonged drought, fire suppression, conifer encroachment, native insects and diseases, and severe browse from wild ungulates limit ecologically important aspen on the landscape. In addition, a newly invasive sap sucking insect, oystershell scale has recently transitioned from an urban and orchard pest to a wildland forest threat of aspen in Arizona. When OSS was recognized as a new threat to aspen in 2017 no management strategies were known and the Arizona Zone of FHP partnered with national forest land managers and researchers at Northern Arizona University, School of Forestry, to develop integrated pest management (IPM) strategies that mitigate the negative effects of OSS infestations on aspen in Arizona. IPM is a science based decision-making process that combines tools and strategies to identify and manage pests, using knowledge of the pest and host biology in combination with biological and environmental monitoring to prevent unacceptable levels of damage, and minimize risk to people and the environment.

Thus far, our team has documented the extent and impacts of OSS across a variety of aspen conditions in Arizona. We have determined that OSS is widespread across much of central Arizona (Figure 40) and causing significant dieback and mortality of aspen below 8,300 feet on national forest lands. We have also determined that OSS is particularly pervasive in aspen enclosures designed to protect aspen regeneration from ungulate browse. Together we have implemented silviculture (coppice and sanitation; Figure 41) experiments within infested aspen enclosures using before-after control-interventions on two national forests. We are evaluating post-treatment fire effects on OSS and will be evaluating efficacy of additional silviculture treatments in 2023 (Figure 40), including chemical treatments using Dinotefuran. Studies to evaluate regionally specific biology of OSS and the role of natural predators are underway in Arizona. New peer-reviewed manuscripts and outreach materials have been developed for land managers and stakeholders. Additional funding sources are being investigated to support this important IPM development. *For more information contact Amanda Grady.*

Figure 41. Aspen regeneration response following coppice treatments to reduce invasive oystershell scale on the Coconino NF near Flagstaff, Arizona. USDA Forest Service photo.

Using Survey123 to Monitor Extent and Severity of Oystershell Scale on All Lands

The USDA Forest Service and partners have documented rapid and widespread OSS impacts, predominantly on national forest system (NFS) lands in Arizona from 2017 to the present. However, it has been realized that OSS is not only an emergent issue in the Southwestern Region, nor does it only affect aspen on NFS lands. In support of broad survey and detection monitoring for invasive oystershell scale, FHP has worked with the Southwestern Region's Geospatial program to create a new Survey123 application (app) called the "Oystershell Scale Survey Form". This app was developed to be used broadly by natural resource managers including state and other federal partners, interested aspen stakeholders such as in academia and other organizations, and by the public. To use the survey, one must download the Survey123 application then search the downloaded surveys for our specific, "Oystershell Scale Survey Form". Once the form is downloaded, users can contribute data to our nationwide and all lands database. Users are prompted to answer questions about who is collecting the data, land ownership, the state and location of observations, the stand type affected, presence or absence of OSS, OSS severity on individual trees and or stands of trees, size class and species impacted, and at the end users are asked to take a close-up picture to validate OSS on an individual tree or shrub and a faraway picture to document stand conditions. Questions are supported by pictures and examples of answers to increase accuracy of data. Please download the app and contribute to our database as you encounter OSS on the landscape or in your backyard. Scan the QR code to open our Oystershell Scale Survey Form if you already have Survey123 downloaded on your device. *For more information contact Isaac Dell or Amanda Grady.*

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Arizona Zone

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Arizona State Department of Forestry and Fire Management and USDA Forest Service, 2022. Arizona Forest Health Alert, Douglas-fir Tussock Moth outbreak along the Mt. Graham Scenic Highway. 2p.

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Forest Health Staff

Arizona Zone

Joel McMillin *(928) 556-2073*

Joel has been the Zone Leader and Supervisory Entomologist for the Arizona Zone since May 2019. His primary duties include supervisory and managerial responsibilities for the Arizona Zone staff and providing oversight of Arizona Cooperative Forest Health program of the State Forester's office. Interests include quantifying impacts of forest insects, bark beetle semiochemicals, stand hazard rating systems for bark beetles and fire-insect interactions. Joel previously served as Group Leader/Supervisory Entomologist with Boise Field Office in the Intermountain Region and Entomologist with the Arizona Zone.

Isaac Dell *(928) 556-2071*

Isaac has been a forest health specialist with the Arizona Zone since August 2022. Duties include conducting the annual aerial detection survey of Arizona, QA/QC of geospatial data on the health of treed areas affected by insects and disease maintained in the National Insect and Disease Survey database, technical and field support, serving as the Alternate Unit Aviation Officer and remote pilot. Previously researched the effects temperature on spruce beetle flight phenology. He was formerly with the Alaska Region (10) since August 2020, and the Rocky Mountain Region (2) from 2015 to 2018.

Monica Gaylord *(928) 556-2074*

Monica has been a forest entomologist with the Arizona Zone since July 2014. Her primary responsibility is providing technical assistance on bark beetle management to land managers. Previously she was assistant research professor at Northern Arizona University. Forest Health interests include how drought and restoration treatments impact tree susceptibility to southwestern pine bark beetles, fire-bark beetle interactions, and single tree protection against bark beetle attacks.

Amanda Grady *(928) 556-2072*

Amanda has been a forest entomologist with the Arizona Zone since October 2011, previously with the Pacific Southwest Region. Primary responsibilities are providing technical assistance on native and exotic forest defoliators and sapsuckers to all federal land managers and statewide monitoring and detection of forest impacts with aerial detection surveys to intensive ground-based monitoring. Current technology transfer interests include developing integrated pest management strategies for emergent exotic pests.

Nicholas Wilhelmi *(928) 556-2075*

Nicholas has been a plant pathologist with the Arizona Zone since January 2017. Primary responsibilities include providing forest disease technical assistance to federal and tribal land managers and hazard tree identification/mitigation training for the Arizona Zone. Current interests include conservation of genetic resistance to white pine blister rust in five needle pines, emerging drought driven pathogens, and aspen monitoring.

New Mexico Zone

Andrew Graves *(505) 842-3287*

Andrew has been the Zone Leader for the New Mexico Zone since October 2020. His primary duties include supervisory and managerial responsibilities for the New Mexico Zone staff. Interests include bark beetle/fungal interactions, the response of insects to drought stressed hosts, pheromones, and DNA analysis of bark beetle species and their hosts. Andrew previously served as a forest entomologist with the New Mexico Zone since October 2010.

John Formby *(505) 842-3285*

John has been a forest health specialist for the New Mexico Zone since August 2022. Primary responsibilities include aerial detection surveys, GIS processing and management, and field and technical assistance. Previously served as the Forest Health Program Manager for the New Mexico Forestry Division where he provided technical assistance and management recommendations for forest pest insects and disease on state and private lands. Previous research interest and experience with southern pine beetle, insect-plant interactions, and ambrosia beetle management and physiology.

Gregory J. Reynolds *(505) 842-3288*

Greg has been a plant pathologist with the New Mexico Zone since January 2017. His primary responsibility is providing technical assistance on forest disease management to national forests and tribal lands as well as managing the hazard tree program for the zone. His current focus is on nursery pathogens (e.g. *Fusarium* spp.), preservation of genetic resistance to white pine blister rust in five-needle pines, and dwarf mistletoe epidemiology. Greg previously served as a plant pathologist (identifier) with the Animal and Plant Health Inspection Service in New Jersey.

Steven Souder *(505) 842-3286*

Steve has been an entomologist with the New Mexico Zone since October 2020. His primary responsibility is providing technical assistance on forest insect management to national forests, tribal lands, and other federal land managers in New Mexico. Steve previously worked on fruit fly research with the Agricultural Research Service in Hawaii for over a decade.

Regional Staff

Crystal Tischler *(505) 842-3284*

Crystal has been the regional aerial survey program manager since September 2022. Crystal previously served as forest health coordinator with the NM office since September 2008. Responsibilities include managing the aerial detection survey program for the region. Her previous work experience is in forest management, fuels reduction, timber sale administration, and community wildfire protection planning.

Zach Hall *(505) 842-3284*

Zach has been a regional survey technician since November 2022. His primary responsibilities include supporting the regional aerial survey, geospatial, and remote sensing programs. He has previously worked as an aircraft sensor operator and as a biologist with the National Park Service.

Appendix: Species Index

Table 6. Common and scientific names for forest insects and diseases* frequently encountered in the Southwestern Region.

Insects		Diseases	
Cedar bark beetles	*Phloeosinus* spp.	Armillaria or shoestring root rot	*Armillaria* spp.
Cone beetles	*Conophthorus* spp.	Black canker	*Ceratocystis fimbriata*
Douglas-fir beetle	*Dendroctonus pseudostugae*	Black leaf spot	*Drepanopeziza populi*
Douglas-fir tussock moth	*Orgyia pseudotsugae*	Comandra blister rust	*Cronartium comandrae*
Fall webworm	*Hyphantria cunea*	Cytospora canker	*Cytospora chrysosperma*
Fir engraver	*Scolytus ventralis*	Dwarf mistletoe	*Arceuthobium* spp.
Flatheaded wood borers	*Buprestidae*	Elytroderma needle cast	*Elytroderma deformans*
Janet's looper	*Nepytia janetae*	False tinder conk	*Phellinus tremulae*
Juniper twig pruner	*Styloxus bicolor*	Fir broom rust	*Melampsorella caryophyllacearum*
Large aspen tortrix	*Choristoneura conflictana*	Ganoderma root rot	*Ganoderma applanatum*
Mountain pine beetle	*Dendroctonus ponderosa*	Gymnosporgangium rust	*Gymnosporangium* spp.
New Mexico fir looper	*Galenara consimilus*	Heterobasidion root rot	*Heterobasidion irregulare, H. occidentale*
Oystershell scale	*Lepidosaphes ulmi*	Hypoxylon canker	*Entoleuca mammata*
Pandora moth	*Coloradia pandora*	Indian paint fungus	*Echinodontium tinctorium*
Pine coneworm	*Dioryctria auranticella*	Ink spot leaf blight	*Ciborinia whetzelii*
Pine engravers	*Ips* spp.	Limb rust	*Cronartium arizonicum*
Pine needle scale	*Chionaspis pinifoliae*	Lophodermella needle cast	*Lophodermella* spp.
Pine sawflies	*Neodiprion* spp., *Zadiprion* spp.	Melampsora rust	*Melampsora* spp.
Pine-feeding needleminers	*Coleotechnites* spp.	Pinyon needle rust	*Coleopsorium jonesii*
Pinyon ips	*Ips confusus*	Biscogniauxia canker of oak	*Biscogniauxia* spp., including *B. mediterranea*
Pinyon needle scale	*Matsucoccus acalyptus*	Red band needle blight	*Dothistroma septosporum*
Ponderosa pine seedworm	*Cydia piperana*	Red belt fungus	*Fomitopsis schrenkii*
Red turpentine beetle	*Dendroctonus valens*	Red ring rot	*Porodaedalea pini*
Roundheaded pine beetle	*Dendroctonus adjunctus*	Red rot	*Dichomitus squalens*
Roundheaded wood borers	*Cerambycide*	Rhabdocline needle cast	*Rhabdocline* spp.
Spruce aphid	*Elatobium abietum*	Schweinitzii root and butt rot	*Phaeolus schweinitzii*
Spruce beetle	*Dendroctonus rufipennis*	Sooty bark canker	*Encoelia pruinosa*
Tiger moth	*Lophocampa ingens*	Spruce broom rust	*Chrysomyxa arctostaphyli*
Twig beetles	*Pityopthorus* spp., *Pityogenes* spp., *Pityoborus secundus*	Sycamore anthracnose	*Apiognomonia veneta*
Western balsam bark beetle	*Dryocoetes confusus*	Tomentosus root rot	*Onnia tomentosa*
Southwestern pine beetle	*Dendroctonus barberi*	True fir needle cast	*Lirula abietis-concoloris*
Western shoot borer	*Eucosma sonomana*	True mistletoe	*Phoradendron* spp.
Western spruce budworm	*Choristoneura fremmanni*	Western gall rust	*Endocronartium harknessii*
Western tent caterpillar	*Malacosoma californicum*	White pine blister rust	*Cronartium ribicola*

*Pathogen scientific names are updated routinely and may not match the regional field guide.