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Forest Insect and Disease Conditions in the Southwestern Region, 2020

Cover photos: Clockwise from left: Spruce beetle-caused tree mortality, Douglas-fir beetle mortality, oystershell scale infested aspen, aecia emerging from southwestern white pine, Emory oak dieback associated with *Biscogniauxia* sp. canker.

Forest Insect and Disease Conditions in the Southwestern Region, 2020

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Conditions in Brief

2020 Weather Summary for the Southwestern U.S.

In 2020, the majority of the Southwestern Region (Arizona and New Mexico) experienced above normal temperatures and below normal precipitation (Figures 1 and 2). In December 2020, most of the region was considered by the United States Drought Monitor (USDM) to be in exceptional drought status. This is the highest level (D4) on the USDM scale and represents significant stress to forests of the Southwestern Region. The Southwest climate region (Arizona, Colorado, New Mexico, and Utah) experienced the hottest, driest June-November season on record. Monsoonal moisture, which normally alleviates the drought stress of spring and early summer, was well below normal and nearly non-existent in most of the region. Conditions continued to become hotter and drier in 2020 in the Southwestern Region.

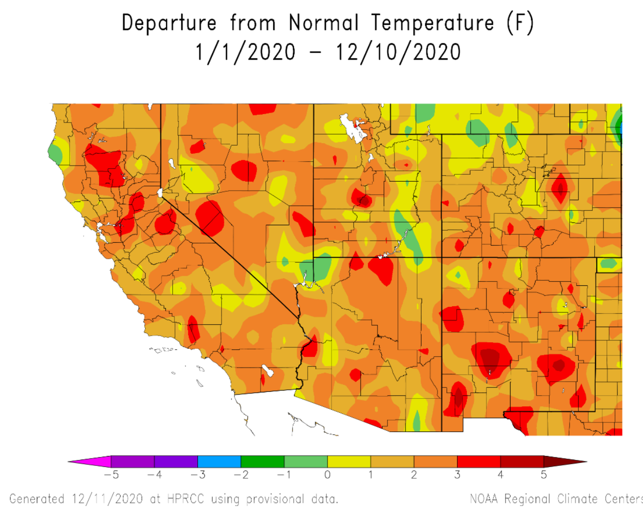

Figure 1. Departure in degrees (F) from normal temperature in the Southwestern U.S. for 2020 (Source: High Plains Regional Climate Center, https://hprcc.unl.edu).

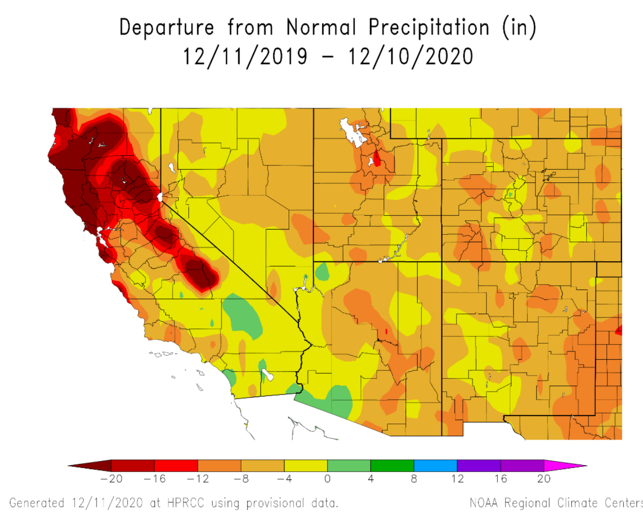

Figure 2. Departure from normal precipitation (inches) in the Southwestern U.S. for 2020 (Source: High Plains Regional Climate Center, https://hprcc.unl.edu).

Regional Forest Insect and Disease Summary

Aerial Survey Summary

In 2020, aerial detection surveys (ADS) covered approximately 20.1 million acres of the Southwestern Region. Aerial surveys primarily covered national forest land (58% of area surveyed), followed by tribal (22%), state and private (16%), and other federal lands (4%) (Table 1, Figure 3). An ArcGIS Online StoryMap summarizing the 2020 aerial detection survey results can be accessed at http://www.fs.usda.gov/goto/r3/healthreport.

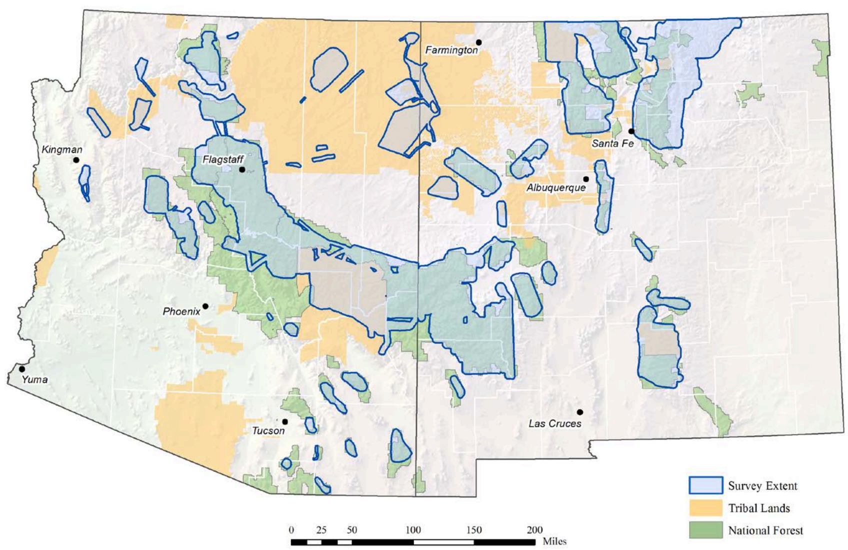

Figure 3. Areas surveyed during 2020 aerial detection survey flights.

Table 1. Aerial detection survey acres flown in 2020 in the Southwestern Region.*

Land ownership	State	Forested	Woodland	Total
National Forest Lands	AZ	3,034,600	2,248,100	5,282,700
Bureau of Land Management	AZ	19,100	54,400	73,500
Department of Defense	AZ	29,100	11,300	40,500
National Park Service	AZ	130,000	163,300	293,300
Tribal	AZ	1,294,100	1,906,800	3,200,900
State and Private	AZ	206,400	286,600	492,900
Arizona Total		**4,713,300**	**4,670,500**	**9,383,800**
National Forest Lands	NM	4,288,000	2,039,400	6,327,400
Bureau of Land Management	NM	36,300	156,900	193,100
Bureau of Reclamation	NM	1,500	< 50	1,500
Department of Defense	NM	0	500	500
Department of Energy	NM	3,100	800	3,900
National Park Service	NM	86,400	16,300	102,700
Tribal	NM	841,000	428,400	1,269,400
State and Private	NM	1,887,700	912,700	2,800,400
New Mexico Total		**7,144,000**	**3,554,900**	**10,698,900**

*Values rounded to the nearest 100; sum of individual values may differ from totals due to rounding.

Bark Beetle Summary

Region-wide, area mapped with bark beetle-caused tree mortality decreased by over 78% from 2019 levels. Tree mortality attributed to bark beetles was observed at varying levels of intensity on 142,060 acres in 2020 compared to 663,500 acres in 2019 (Table 2). Acreage with mortality decreased for all bark beetle species except spruce beetle, which increased by about 52%. Most of the increased spruce beetle activity occurred on the Santa Fe National Forest (NF) in northern New Mexico, which accounted for over 60% of spruce beetle activity in the region (Table 2). Notable increases in spruce beetle-related mortality were also observed in Arizona, primarily on White Mountain Apache Tribal Lands which accounted for about 80% of damage statewide. Although there was an overall decrease in bark beetle-related mortality as reported by ADS, continued drought conditions and lack of monsoonal moisture led to late season mortality in parts of the region that may not have been captured by ADS. This mortality is likely a combination of drought stress and bark beetle activity.

Bark beetle-related ponderosa pine mortality was observed across Arizona with the exception of Havasupai and Hopi Tribal Lands (Table 2). Acres with ponderosa pine mortality declined from 166,890 acres with mortality in 2019 to 62,570 acres in 2020. Ponderosa pine bark beetles were the most prevalent mortality agent mapped in Arizona in 2020. Although there was a decrease observed statewide, the Coconino and Kaibab NFs saw increases in ponderosa pine mortality, with acres affected on the Coconino more than doubling from 15,120 in 2019 to 32,730 in 2020. The Coconino and Kaibab NFs accounted for 70% of acres mapped with ponderosa mortality in Arizona. Pinyon mortality also decreased on all land ownerships throughout the state (Table 2). Most pinyon mortality, about 79%, was mapped on Navajo Tribal Lands, although levels observed there were 90% lower than those observed in 2019.

Ponderosa pine mortality mapped in New Mexico decreased by 89%, with most land ownerships having <5 acres of mortality (Table 2). Most ponderosa mortality was observed on the Gila NF, which accounted for 62% of total ponderosa mortality in New Mexico (Figure 4). The majority of bark beetle-related mortality in New Mexico was attributed to spruce beetle, which accounted for over 50% of total bark beetle activity in the state and increased from 21,790 acres affected in 2019 to 31,020 in 2020. Acres with spruce beetle-related mortality were primarily mapped on the Santa Fe (66%) and Carson (25%) NFs (Table 2).

Figure 4. Ponderosa pine mortality near the Buzzard Fire, Gila National Forest, from post-fire stress and subsequent insect activity.

Table 2. Bark beetle[1] incidence by ownership (acres) from aerial detection surveys in 2020 in Arizona and New Mexico[2].

Ownership[3]	Ponderosa pine bark beetles[4]	Pinyon ips	Douglas-fir beetle	Spruce beetle	Western balsam bark beetle	Fir engraver	Cedar bark beetles
Apache-Sitgreaves NFs	5,200	10	130	130	20	120	10
Coconino NF	32,730	20	460	< 5	< 5	460	570
Coronado NF	200		70	< 5		340	< 5
Kaibab NF	11,340	50	50	< 5	< 5	10	< 5
Prescott NF	220	< 5	< 5			40	20
Tonto NF	470		100			< 5	< 5
Bureau of Land Management	20	60					< 5
Department of Defense	70						
Canyon de Chelly Nat. Mon.	10	1,910	< 5				
Chiricahua Nat. Mon.	< 5						
Grand Canyon Nat. Park	5,330	10	< 5	60			60
Lake Mead Nat. Rec. Area	0	< 5					10
Saguaro Nat. Mon.	10						
Sunset Crater Nat. Mon.	< 5						
Walnut Canyon Nat. Mon.	10	< 5					
Havasupai Tribal Lands	0	< 5					< 5
Hopi Tribal Lands	0	80					50
Hualapai Tribal Lands	10	20					< 5
Navajo Tribal Lands	980	8,580	330	250		< 5	800
San Carlos Apache Tribal Lands	880	< 5	< 5				< 5
White Mtn Apache Tribal Lands	4,030	30	220	1,800	190	70	< 5
Other Tribal Lands	< 5	< 5					
State & Private	1,050	40	< 5			60	1,190
Arizona Total	**62,570**	**10,820**	**1,370**	**2,240**	**210**	**1,090**	**2,720**
Carson NF	70	10	880	7,910	< 5	30	
Cibola NF	1,830	80	1,090		10	210	
Gila NF	7,820	180	1,040		< 5	40	< 5
Lincoln NF	210	10	70	40	30		
Santa Fe NF	290	< 5	7,470	20,390	30	200	< 5
Bureau of Land Management	10	70	< 5				20
Department of Defense	< 5						
Bandelier Nat. Mon.							
El Malpais Nat. Mon.	< 5						
Valles Caldera Nat. Preserve	< 5		140	< 5			
Acoma Pueblo	< 5	< 5					
Isleta Pueblo	130	< 5	< 5			< 5	
Jemez Pueblo							
Jicarilla Apache Tribal Lands	< 5	< 5	40	90			
Laguna Pueblo	< 5		< 5				
Mescalero Apache Tribal Lands	60	< 5	150	< 5	< 5	< 5	
Navajo Tribal Lands	460	2,900	520	440		< 5	150
Picuris Pueblo	< 5		< 5				
Santa Clara Pueblo							
Taos Pueblo	< 5	< 5	670	< 5		< 5	
Zia Pueblo	< 5						
Zuni Pueblo	< 5	< 5	< 5				
State & Private	1,710	380	690	2,130	10	210	90
New Mexico Total	**12,580**	**3,650**	**12,760**	**31,020**	**80**	**690**	**260**
Grand Total	**75,160**	**14,470**	**14,130**	**33,250**	**290**	**1,780**	**2,980**

[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 land ownership, 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

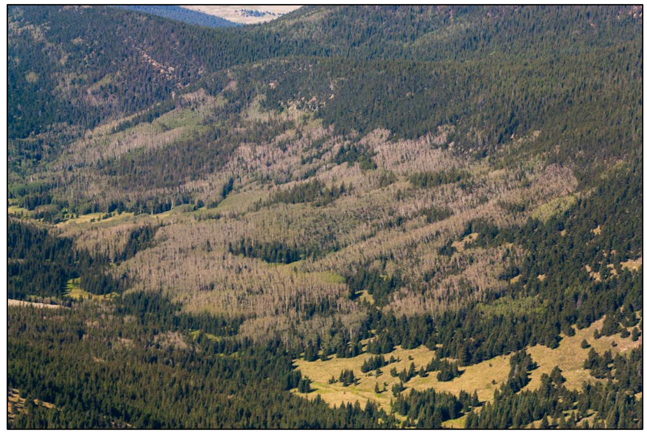

Figure 5. Aspen defoliation observed in New Mexico.

Defoliation from insects and diseases (including agents not shown in Table 3) increased slightly across the region from 383,130 acres in 2019 to 426,880 in 2020, largely driven by an increase in acres affected by spruce budworm defoliation. Most of the defoliation occurred in New Mexico, primarily on the Carson NF (Table 3). Aspen damage, which includes defoliation, dieback, and mortality, was also predominantly mapped in northern New Mexico (Figure 5). In Arizona, aspen damage was concentrated on the Kaibab NF, where ungulate herbivory, lack of overstory recruitment, and the invasive oystershell scale are major contributors to dieback and mortality. Other defoliating agents each accounted for less than 5% of total defoliation in the region (Table 3). Defoliation from spruce aphid decreased in Arizona from 8,100 acres in 2019 to 2,230 in 2020. Most of the damage was observed on White Mountain Apache Tribal Lands. Douglas-fir tussock moth activity declined across the region, affecting only 200 acres compared to 3,060 acres in 2019 (Table 3). The Janet’s looper outbreak in New Mexico also declined from 5,600 acres with defoliation in 2019 to 2,580 acres in 2020.

In lower elevation forests, a 70% decrease in pinyon needle scale damage was observed across the region. This trend was driven by observations in New Mexico, where pinyon needle scale damage decreased from 45,510 acres detected in 2019 to only 840 acres in 2020. Pinyon needle scale damage increased in Arizona from 340 acres reported in 2019 to 12,860 acres in 2020. The amount of observable pinyon needle scale damage fluctuates from year to year more than the actual acres with damage fluctuate. Drought conditions may have contributed to the amount of observable pinyon needle scale damage detected in Arizona in 2020 (Table 3).

Table 3. Defoliation[1] and all aspen damage incidence by ownership (acres) from aerial detection surveys in 2020 in Arizona and New Mexico[2].

Ownership[3]	Western spruce budworm	Aspen damage[4]	Douglas-fir tussock moth	Sawfly on Ponderosa	Pinyon needle scale	Spruce aphid
Apache-Sitgreaves NFs		590			70	790
Coconino NF	120	740	90	620	1,510	10
Coronado NF		30				
Kaibab NF	410	4,290		< 5		
Prescott NF					2,730	
Tonto NF		10	50		2,420	
Bureau of Land Management		10			80	
Department of Defense						
Canyon de Chelly Nat. Mon.						
Chiricahua Nat. Mon.						
Grand Canyon Nat. Park		20			40	
Lake Mead Nat. Rec. Area						
Saguaro Nat. Mon.						
Sunset Crater Nat. Mon.						
Walnut Canyon Nat. Mon.						
Havasupai Tribal Lands						
Hopi Tribal Lands						
Hualapai Tribal Lands					1,270	
Navajo Tribal Lands		1,760			870	
San Carlos Apache Tribal Lands					220	
White Mtn Apache Tribal Lands		750	40		2,450	1,430
Other Tribal Lands						
State & Private		90		10	1,200	
Arizona Total	**530**	**8,310**	**190**	**630**	**12,860**	**2,230**
Carson NF	114,310	21,440				
Cibola NF	3,660	2,140			130	
Gila NF		240		230	40	
Lincoln NF	2,360	640			10	
Santa Fe NF	77,400	14,820			20	
Bureau of Land Management	40					
Department of Defense						
Bandelier Nat. Mon.	< 5	20				
El Malpais Nat. Mon.						
Valles Caldera Nat. Preserve	5,300	130				
Acoma Pueblo						
Isleta Pueblo						
Jemez Pueblo	160					
Jicarilla Apache Tribal Lands	5,640	60				
Laguna Pueblo	70	10				
Mescalero Apache Tribal Lands		90			480	
Navajo Tribal Lands		2,220	20			
Picuris Pueblo	10					
Santa Clara Pueblo		50				
Taos Pueblo	3,120	2,540				
Zia Pueblo						
Zuni Pueblo						
State & Private	84,660	16,400		770	160	
New Mexico Total	**296,750**	**60,810**	**20**	**1,000**	**840**	
Grand Total	**297,270**	**69,120**	**200**	**1,640**	**13,700**	**2,230**

[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 land ownership, 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 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. Our current estimates (1,873,000 acres and 2,073,000 acres across all ownerships for Arizona and New Mexico, respectively) 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 occur sporadically based on environmental conditions.

White pine blister rust, an invasive disease caused by an introduced fungus, 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 and it continues to spread into new areas.

Status of Major Insects

Bark Beetles

As previously mentioned, overall totals of tree mortality attributed to bark beetles for most conifers decreased across the region in 2020 (Table 2). Acres with pinyon mortality decreased throughout the region with most of the damage located on Navajo Tribal Lands. Ponderosa mortality decreased in New Mexico and was observed on <5 acres on many land ownerships in the state. Much of this mortality (62%) occurred on the Gila NF. Ponderosa mortality in Arizona declined statewide except on the Coconino and Kaibab NFs. Fir engraver activity decreased overall across the region with local increases observed on White Mountain Apache Tribal Lands and the Apache-Sitgreaves NFs in Arizona and Santa Fe NF in New Mexico. Douglas-fir beetle activity generally decreased region-wide but increased on the Gila NF. Western balsam bark beetle activity decreased region-wide but increases in activity were observed on the Coronado NF in Arizona and Cibola NF in New Mexico. The only region-wide increase in bark beetle activity observed was related to spruce beetle, 93% of which was in New Mexico, largely on the Santa Fe NF. Because ground checks are not feasible at all locations in all years, most dying conifer trees are attributed to bark beetles. In some systems root diseases, drought and other agents contribute to mortality.

Pinyon-Juniper Forest Type

The pinyon-juniper forest type had a region-wide decrease in bark beetle-attributed mortality (Figure 6). Total area with mortality observed in the pinyon-juniper forest type decreased by about 95%, dropping from 320,070 acres in 2019 to 17,450 in 2020. The majority of the damage attributed to pinyon ips was recorded in Arizona (Table 2), where mortality decreased from 230,100 acres in 2019 to 10,820 acres in 2020. Similar decreases in pinyon ips activity were observed in New Mexico where acres mapped decreased from 45,590 in 2019 to 3,650 acres in 2020. Observations of increased activity in 2019 prompted a special aerial survey flight over a large portion of the northwestern part of New Mexico that is not typically surveyed. This special survey, in addition to increased mortality on Navajo Tribal Lands, contributed to the increased level of activity mapped in 2019. Due to decreased activity in 2020, no special survey was conducted. Navajo Tribal Lands accounted for 79% of total pinyon mortality region-wide (Figure 7). Juniper mortality attributed to bark beetles was also mostly observed in Arizona and was largely focused on Navajo Tribal Lands and state and private lands. Though Navajo Tribal Lands accounted for most damage in this forest type, it is important to note that levels recorded, although still elevated, decreased from last year.

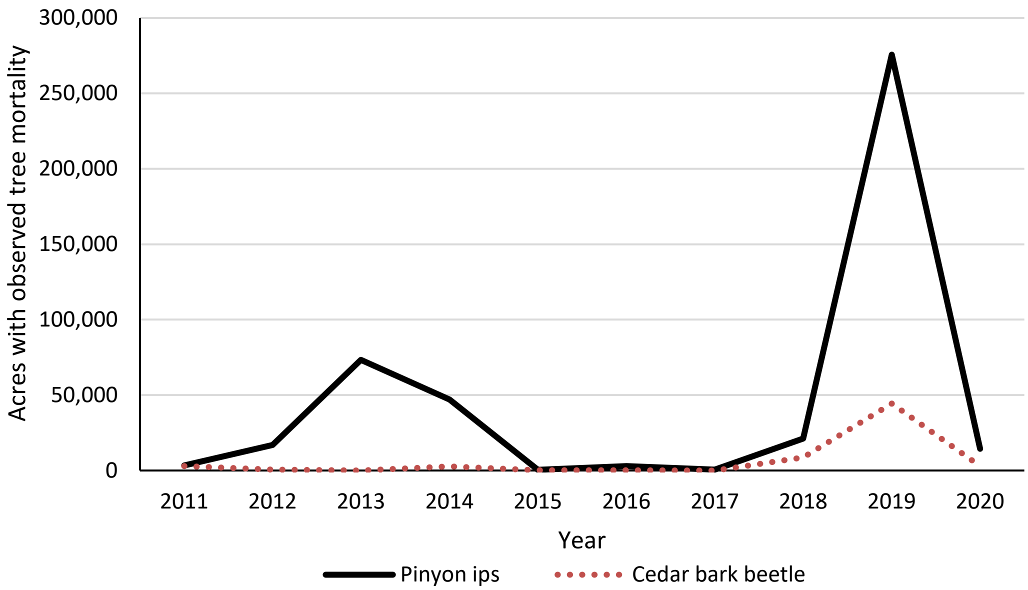

Figure 6. Pinyon-juniper mortality associated with pinyon ips and cedar bark beetles in the Southwestern Region over the last ten years.

Pinyon Ips

Ips confusus
Host: Pinyon pine

In 2020, acres with pinyon mortality decreased by over 94%, with 14,470 acres mapped in 2020 compared to 275,690 in 2019 (Figure 6). Most of the mortality (75%) occurred in Arizona, where acres with mortality decreased from 230,100 mapped in 2019 to 10,820 in 2020. Similar decreases occurred in New Mexico where acres with pinyon mortality dropped from 45,590 acres in 2019 to 3,650 in 2020. Navajo Tribal Lands accounted for the majority (79%) of all the pinyon mortality in both Arizona and New Mexico (Figure 7, Table 2). Acres with pinyon mortality mapped on Navajo Tribal Lands decreased by about 94% in 2020, dropping from 191,300 acres in 2019 to 11,480 in 2020. This decrease was partially due to reduced survey coverage in 2020. In 2019 a special survey for pinyon mortality was conducted across much of northwest New Mexico, covering additional Navajo Tribal Lands. This survey was not conducted in 2020.

Figure 7. Pinyon mortality observed on the Kaibab National Forest.

Cedar Bark Beetles

Phloeosinus spp.
Host: Junipers and Arizona cypress

Cedar bark beetle activity decreased by about 93% region-wide, dropping from 44,380 acres in 2019 to 2,980 in 2020 (Figure 6). Arizona reported over 91% of the juniper mortality for the region. Acres with juniper mortality decreased in Arizona from 41,830 in 2019 to 2,720 in 2020, with the majority of mortality occurring at lower elevations of the host range on state and private lands (43%), Navajo Tribal Lands (29%), and the Coconino NF (21%) (Table 2). Acres with mortality also decreased in New Mexico, with 2,550 acres mapped in 2019 and only 260 acres mapped in 2020. Similar to pinyon ips activity, this decrease was likely influenced by reduced surveyed area as a special survey of northwestern New Mexico was not conducted in 2020. Much of the mortality was mapped on the Navajo Tribal Lands (58%) and state and private lands (35%) (Table 2). Juniper mortality is typically attributed to beetle-kill; however, drought conditions likely play a significant role.

Ponderosa Pine Forest Type

In the Southwestern Region, ponderosa pine supports 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 multiple species co-occurring within the same trees.

There was a 73% decrease in ponderosa pine mortality in 2020, with 75,160 acres of mortality mapped compared to 280,020 in 2019 (Figure 8). The majority (83%) occurred in Arizona. Most of the mortality mapped in Arizona was located on the Coconino NF (Figure 9), where ponderosa pine mortality more than doubled, increasing from 15,120 acres in 2019 to 32,730 in 2020. Mortality on the Coconino NF was evenly distributed across the Flagstaff and Mogollon Rim Ranger Districts. There was also an increase on the Kaibab NF, where ponderosa pine mortality, increased from 3,970 acres in 2019 to 11,340 in 2020; most of the mortality was mapped on the North Kaibab RD. Ground surveys found numerous beetle species, including several species of engraver beetles, southwestern pine beetle (formerly grouped with western pine beetle), roundheaded pine beetle, and red turpentine beetle.

In New Mexico, ponderosa pine mortality decreased in total statewide acres from 113,130 in 2019 to 12,580 in 2020. Most of the mortality (62%) was located on the Gila NF, which was the only area where increases in ponderosa pine mortality were observed (Table 2). This activity was largely focused on the Reserve RD, particularly in the area affected by the Buzzard Fire.

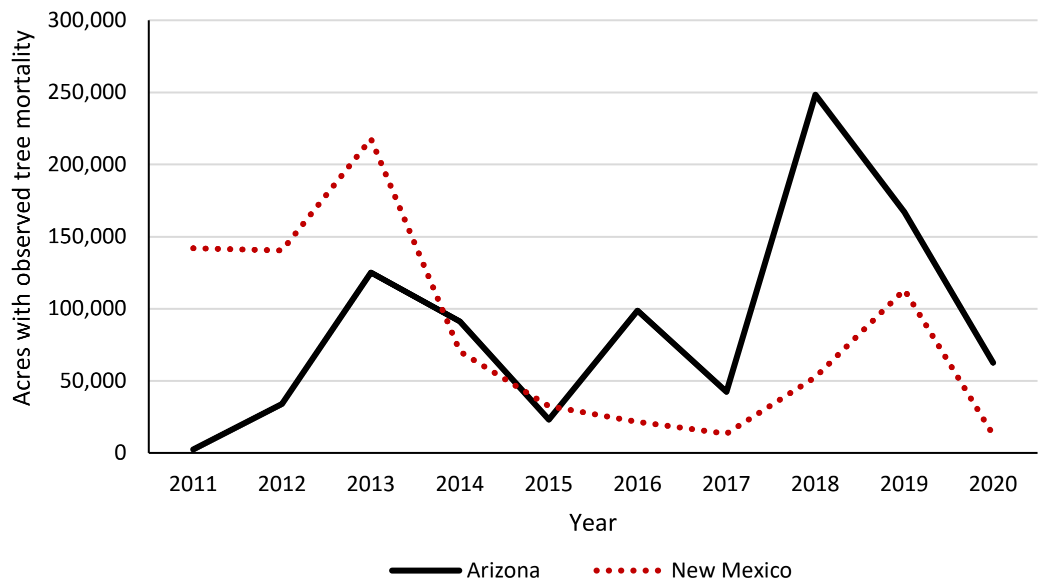

Figure 8. Ponderosa pine mortality attributed to bark beetles in the Southwestern Region over the last ten years.

Figure 9. Ponderosa pine mortality attributed to bark beetles on the Coconino National Forest.

Mixed Conifer Forest Type

Mixed conifer forest occurs at higher elevations starting around 8,000 feet but may also be present at lower elevations that receive sufficient moisture. Common species in mixed conifer forests include Douglas-fir, southwestern white pine, ponderosa pine and, at the higher end of the elevation distribution, Engelmann spruce and fir species. Bark beetle activity in the mixed conifer forests of the Southwestern Region is commonly associated with stress caused by wildfires, severe defoliation events, root diseases, and drought. Douglas-fir beetle and fir engraver activity in mixed conifer forests decreased by over 60% in 2020 (Figure 10). Most of the mortality (80%) was related to Douglas-fir beetle activity in New Mexico (Table 2).

Douglas-fir Beetle

Dendroctonus pseudotsugae
Host: Douglas-fir

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 scorch, infected by dwarf mistletoe or root disease, or trees experiencing severe defoliation. Generally, Douglas-fir beetle will only affect small pockets or individual trees, but infestations may grow to larger outbreaks. These outbreaks can be exacerbated by drought.

In 2020, Douglas-fir mortality from Douglas-fir beetle decreased by 54%, with 30,980 acres mapped in 2019 compared to 14,130 in 2020 (Figure 10). New Mexico accounted for over 90% of the total Douglas-fir beetle activity in the region, with most occurring on the Santa Fe NF, where 7,470 acres with mortality were mapped (Figure 11). This is a decrease from the 10,130 acres mapped in 2019. Douglas-fir beetle activity increased on the Gila NF, from 120 acres in 2019 to 1,040 acres in 2020. There were also increases on the Taos Pueblo and Mescalero Apache Tribal Lands, which increased by 170 and 120 acres, respectively. All ownerships in Arizona experienced decreases in mortality attributed to Douglas-fir beetle. For example, on the Apache-Sitgreaves NFs, acres with mortality dropped from 3,120 acres in 2019 to 130 in 2020, most of which was outside the Wallow Fire perimeter. Navajo Tribal Lands in Arizona also experienced a decrease, dropping from 7,910 acres with mortality in 2019 to 330 in 2020.

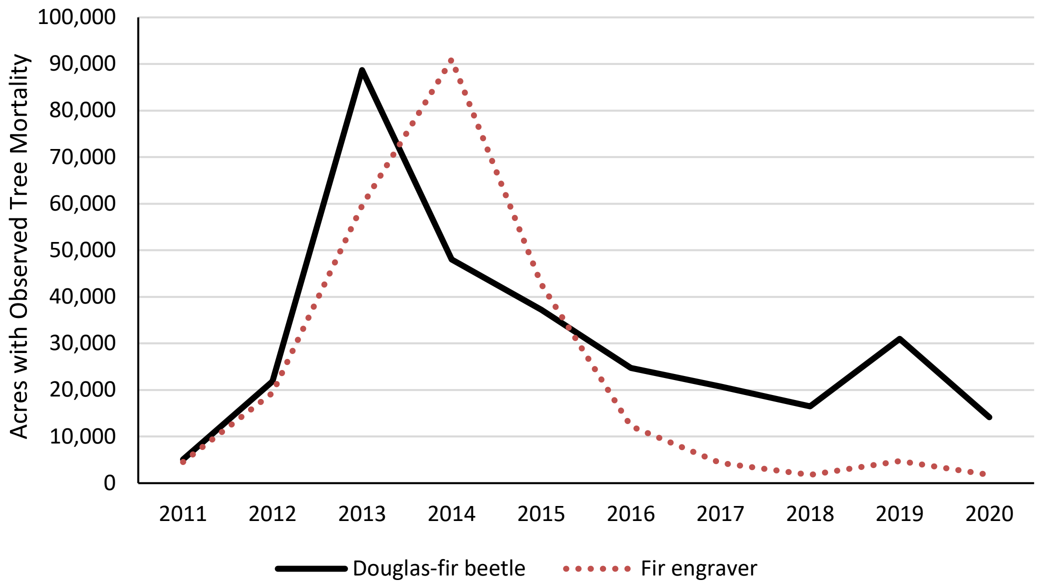

Figure 10. Mixed conifer mortality associated with Douglas-fir beetle and fir engraver in the Southwestern Region over the last ten years.

Figure 11. Douglas-fir mortality from Douglas-fir beetle observed in the Santa Fe National Forest.

Fir Engraver

Scolytus ventralis
Host: White fir

White fir mortality from fir engraver beetles often occurs when trees are exposed to stress caused by drought, increased competition due to high stand densities, defoliation, or root diseases. The resulting tree mortality may be more prevalent on drier south- and west-facing slopes. Mortality can occur in all size and age classes.

White fir mortality decreased by over 62% region-wide, with total acres mapped reduced from 4,760 acres in 2019 to 1,780 in 2020 (Figure 10). In Arizona, fir engraver activity decreased from 3,240 acres mapped in 2019 to 1,090 in 2020. Most of the mortality occurred on the Coconino NF (42%), where area affected remained similar to 2019 levels, decreasing from 470 acres in 2019 to 460 acres in 2020. Activity on the Coronado NF, which comprised 31% of the damage recorded in Arizona, increased slightly from 300 acres in 2019 to 340 acres in 2019. This was the only increase observed in Arizona. Most white fir mortality in New Mexico was reported on the Santa Fe (29%) and Cibola (30%) NFs as well as on state and private lands (30%) (Table 2). Fir engraver activity spiked on the Cibola NF from 2013 to 2016 but has remained low in recent years. In 2020, acres affected increased from 160 in 2019 to 210 in 2020 on the Cibola NF. In addition, Navajo Tribal Lands in New Mexico experienced a decrease in acres affected by fir engraver, decreasing from 900 acres in 2019 to <5 acres in 2020.

Ips

Ips bonanseai
Host: Southwestern white pine

Ground surveys from 2018-2020 identified *Ips bonanseai* attacking and killing southwestern white pines within the perimeter of the Frye Fire in the Pinaleño Mountains on the Safford RD, Coronado NF. Mountain pine beetle was also present in most of these dead trees. *Ips bonanseai* beetles are not generally considered aggressive tree killers. It is suspected that the beetles were exploiting trees stressed by ongoing drought and the 2017 fire. This area will continue to be monitored with ground surveys in 2021 as part of the beetle suppression project occurring in the Frye Fire area. More information can be found in the "Other Entomology and Pathology Activities in 2020" section of this document under "Frye Fire, Coronado National Forest".

Spruce-fir Forest Type

At around 9,000 feet elevation, mixed conifer forests transition to spruce-fir forests. Engelmann spruce and corkbark fir are the primary tree species, but blue spruce, southwestern white, limber pine, Rocky Mountain bristlecone pine, and aspen may also be present. Bark beetle activity in spruce-fir forests of the Southwest is usually associated with forest disturbance events, root disease and severe drought.

Spruce Beetle

Dendroctonus rufipennis
Host: Spruce

Spruce beetle was the only bark beetle in the Southwestern Region to increase in activity in 2020 (Figure 12, Table 2). Region-wide acres with spruce mortality attributed to spruce beetle increased from 21,910 in 2019 to 33,250 in 2020. In Arizona, spruce beetle activity increased from 120 acres in 2019 to 2,240 in 2020. Most of the activity (80%) occurred on Mount Baldy on White Mountain Apache Tribal Lands in east central Arizona, primarily in areas previously impacted by spruce aphid outbreaks. Spruce beetle activity increased on White Mountain Apache Tribal Lands from only 120 acres in 2019 to 1,800 in 2020. Other notable increases in Arizona in 2020 occurred on Navajo Tribal Lands and on the Apache-Sitgreaves NFs which increased by 250 and about 130 acres respectively. Spruce beetle activity has been steadily increasing over the past three years on the Apache-Sitgreaves NFs, mostly on the Springerville RD. New Mexico accounted for the most spruce beetle attributed mortality, representing 93% of the total activity region-wide. Stands experiencing several years of bark beetle activity have recorded >50% spruce mortality, and little new activity was observed in these areas. The Santa Fe NF increased in acres affected from 13,970 acres in 2019 to 20,390 in 2020 (Figure 13), however, much of this area had been previously affected by spruce beetle and overall intensity levels were low. More notable increases were observed on the Carson NF, which increased from 5,610 acres in 2019 to 7,910 in 2020, and on Navajo Tribal Lands, which increased from <5 acres in 2019 to 440 in 2020. State and private lands in New Mexico also saw an escalation in spruce beetle activity, increasing from 1,950 acres in 2019 to 2,130 in 2020.

Western Balsam Bark Beetle

Dryocoetes confusus
Hosts: Corkbark fir

Fir mortality attributed to western balsam bark beetle (WBBB) decreased from 5,830 acres in 2019 to 290 in 2020 (Figure 12). Most of the mortality attributed to WBBB was located in Arizona, which accounted for over 72% of damage recorded region-wide. Within Arizona, mortality was primarily located on White Mountain Apache Tribal Lands where WBBB activity increased from 10 acres in 2019 to 190 in 2020 and accounted for over 90% of the mortality in the state. No WBBB activity was observed on Navajo Tribal Lands in Arizona, a decrease from 790 acres mapped in 2019. New Mexico also had reduced acres affected by WBBB, decreasing from 5,030 acres in 2019 to 80 in 2020. Decreases in WBBB activity were observed across all ownerships in New Mexico except the Santa Fe NF, where activity increased slightly from <5 acres in 2019 to 30 in 2020. The largest decline was observed on Navajo Tribal Lands, from 4,510 acres in 2019 to <5 acres in 2020. Similarly, activity on state and private lands decreased from 350 acres in 2019 to <5 in 2020.

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.

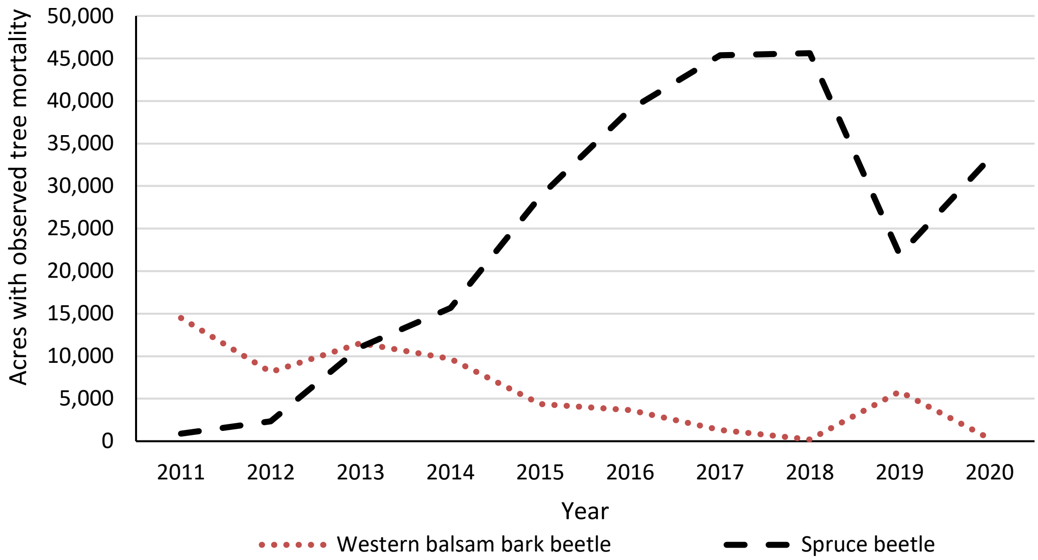

Figure 12. Tree mortality in spruce-fir forests attributed to spruce beetle and western balsam bark beetle in the Southwestern Region over the last ten years.

Figure 13. Spruce beetle activity in the upper portion of the Rito Maestas drainage in the Pecos Wilderness, Santa Fe National Forest; the oldest dead trees appear gray, more recent dead red/purple, and current fading trees yellow.

Defoliators

Acres observed with damage from defoliators (including less prominent agents not included in Table 3) increased slightly from 383,130 in 2019 to 426,880 acres in 2020. Regionally, acres with defoliation attributed to spruce aphid, Janet's looper, and pinyon needle scale decreased. Aspen damage, including defoliation, also decreased, but increases were observed on some forests, particularly the Carson NF in New Mexico and the Kaibab NF in Arizona. Douglas-fir tussock moth acres decreased the most, with levels down 93% compared to 2019 across the region. Needleminer and pine sawfly-caused defoliation, though fairly localized, increased region-wide. Needleminer was only observed in New Mexico, primarily on the eastern slopes of the Sangre de

Cristo Mountains on state and private lands. New Mexico also accounted for the majority of pine sawfly damage in the region (Table 3). Western spruce budworm, which accounted for the most acres of defoliation in the region, increased by 55% growing to 297,270 acres region-wide. Most of the damage (99%) occurred in New Mexico, primarily on the Carson NF.

Pinyon-Juniper Forest Type

Pinyon Needle Scale

Matsucoccus acalyptus
Host: Pinyon pine

Figure 14. Defoliation attributed to pinyon needle scale on the Prescott National Forest.

After an increase from 2018 to 2019, damage attributed to pinyon needle scale decreased in 2020 by 70%, dropping from 45,850 acres in 2019 to just 13,700 in 2020 (Table 3). Contrary to 2019, most of the damage, over 93%, occurred in Arizona (Figure 14). Large increases were observed on White Mountain Apache Tribal Lands, which increased from zero acres in 2019 to 2,450 in 2020, and on the Tonto NF, which increased from zero acres in 2019 to 2,420 in 2020. Similar increases in activity were observed on the Prescott and Coconino NFs, and Hualapai Tribal Lands which increased in 2020 by 2,730, 1,510 and 1,230 acres, respectively. New Mexico experienced a 98% decrease in observed defoliation by pinyon needle scale, dropping from 45,510 acres in 2019 to 840 acres in 2020. The large increase in 2019 was due in part to highly visible defoliation in the spring along with some early season ground and aerial surveys. This damage was not as visible in 2020 and there were reduced ground visits in the spring. Mescalero Apache Tribal Lands accounted for most of the damage that was observed, with 480 acres mapped in 2020, a decrease from 1,750 acres mapped in 2019.

Repeated defoliation from this insect can cause reduced growth and stunted needles. In severe outbreaks, small trees may be killed directly while larger trees are often predisposed to pinyon ips. Depending upon the severity of the defoliation and timing of flights and ground surveys, this damage can be quite difficult to observe. In addition, it is difficult to discern between old and new damage; thus, our numbers may vary from year-to-year more than actual incidence on the landscape.

Ponderosa Pine Forest Type

Pandora Moth

Coloradia pandora
Host: Ponderosa pine

The pandora moth outbreak first reported from aerial survey on the Kaibab Plateau in 2013 is expected to end after four cycles of damage, as occurred during the previous outbreak reported at this location from 1978-1984. Visible damage from this insect is caused by feeding during the caterpillar stage, which occurs every other year during outbreaks due to the two-year life cycle. Defoliation continued to subside in extent and severity during the fourth cycle as reported in 2019. No damage was reported during this non-feeding year, and little damage is anticipated in 2021.

Pine Sawflies

Neodiprion and *Zadiprion* spp.
Host: Ponderosa pine

Pine sawfly damage increased slightly across the region, rising from 1,470 acres in 2019 to 1,640 in 2020. This was driven by a 630 acre increase in Arizona where no pine sawfly activity was observed in 2019. Damage was primarily mapped on the Coconino NF where acres affected by pine sawflies rose from zero acres in 2019 to 620 acres in 2020. Pine sawfly damage was verified on open-grown small diameter trees around Hart Prairie, north of Flagstaff, Arizona. Approximately 85 acres were affected at this location. Pine sawflies were not validated as the causal agent of crown discoloration observed south of Mormon Lake where most of the damage in Arizona occurred. Although New Mexico still accounted for most of the pine sawfly damage in the region, area affected there decreased from 1,470 acres in 2019 to 1,000 in 2020. The decrease was primarily due to reduced activity on the Cibola NF, which decreased from 950 acres in 2019 to zero in 2020. In contrast, activity on state and private lands increased from 520 acres in 2019 to 770 in 2020 due to a resurgence of activity on the Luera Mountains, which has had an ongoing outbreak (Figure 15). Additionally, two new areas of suspected pine sawfly activity were detected on the Gila NF, affecting 230 acres.

Figure 15. Pine sawfly damage observed on state and private lands on the Luera Mountains, New Mexico.

Pine Needleminer

Coleotechnites ponderosae
Host: Ponderosa pine

Ponderosa pine defoliation attributed to ponderosa pine needleminer has been mapped in New Mexico for the past three years. Damage has primarily been located on state and private lands along the eastern slopes of the Sangre de Cristo Mountains neighboring the Carson NF. This defoliation affected nearly 48,990 acres in 2020, an increase from over 47,000 acres in 2019. State and private lands, namely Vermejo Ranch, accounted for 90% of the total damage attributed to pine needleminer in 2020, with 44,180 acres mapped (Figure 16). It is not known whether needleminer is solely responsible for the activity over the entire Vermejo area as defoliation from needleminer has only been linked to specific locations. Ponderosa pine discoloration mapped on the Carson NF surrounding Tres Piedras was also confirmed to be new needleminer activity. No needleminer activity was observed in Arizona in 2020.

Figure 16. Needleminer damage observed on Vermejo Ranch in New Mexico. Affected trees along the ridge tops appear a yellowish color.

Mixed Conifer Forest Type

Aspen Defoliation and Mortality

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

Aspen damage, a combination of defoliation, mortality, and dieback caused by biotic and abiotic damage, decreased across the region from 78,170 acres in 2019 to 69,120 in 2020. Most of the damage (88%) was observed in New Mexico (Table 3). Arizona experienced a 76% reduction in acres of aspen damage, decreasing from 34,160 acres in 2019 to 8,310 in 2020. Activity on the Kaibab NF, which accounted for over half the damage in Arizona, increased from 250 acres in 2019 to 4,290 in 2020 and was the only area in Arizona to increase in acres affected (Figure 17). Navajo Tribal Lands saw the largest reduction in acres affected, decreasing from 15,360 acres in 2019 to 1,760 in 2020, a nearly 89% decrease. Decreases in damage were also recorded on White Mountain Apache Tribal Lands and the Apache-Sitgreaves NFs, which decreased by 9,180 and 6,440 acres, respectively.

Ground surveys in northern Arizona, particularly on the Coconino and Kaibab NFs, indicate significant declines in aspen recruitment, establishment, and overstory condition. This decline, which is associated with insects and disease, ungulate browse, climate, and other factors, is reducing resilience and longevity of aspen. In addition, an exotic insect, oystershell scale, has been increasingly observed in forest settings. Oystershell scale has been observed for decades in urban areas, but widespread, severe impacts on aspen in forest settings have only recently been documented. More information on aspen monitoring in Arizona may be found in the "Other Entomology and Pathology Activities in 2020" section of this document under "Aspen Monitoring in Northern Arizona".

In contrast, aspen damage continued to increase in New Mexico, with 60,810 acres of damage observed in 2020 compared to 44,010 in 2019. The Carson NF experienced the largest increase in acres affected, increasing from only 5,000 acres in 2019 to 21,440 in 2020. The Santa Fe NF and state and private lands also saw elevated activity, increasing by 8,920 and 12,320 acres, respectively. The damage on the Carson and Santa Fe NFs has primarily been defoliation by western tent caterpillar in recent years, but large aspen tortrix was also observed affecting large areas of high elevation aspen in the Sangre de Cristo Mountains in 2020. In addition, defoliation by aspen leaf beetle was observed in the fall on approximately 200 acres within the Viveash Fire scar in the Santa Fe NF and adjacent private lands. Aspen leaf beetle activity is not common in New Mexico, and, in addition to spring western tent caterpillar feeding, places additional stress on affected aspen. Activity on Navajo Tribal Lands in New Mexico, which accounted for most of the damage mapped in 2019, decreased by 91% from 25,280 acres in 2019 to 2,220 in 2020.

Figure 17. Aspen defoliation on the Kaibab National Forest.

Douglas-fir Tussock Moth

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

Figure 18. Parasitized Douglas-fir tussock moth pupa.

Douglas-fir tussock moth (DFTM) activity decreased by over 93% in 2020, dropping from 3,060 acres in 2019 to 200 acres in 2020. Most of the damage was mapped in Arizona, primarily on the Coconino and Tonto NFs. A decrease in activity was observed on the Coconino NF, from 570 acres detected in 2019 to 90 acres in 2020. Although small areas continued to be affected on the Mogollon Rim in 2020, the DFTM outbreak that began in 2018 has mostly subsided at that location. A new DFTM hotspot was detected in 2019 in the Pinal Mountain Recreation Area on the Globe RD, Tonto NF. Early warning traps, sequential egg mass sampling, and larval sampling all indicated the population was increasing in this area in 2019 through 2020. However, the amount of damage detected decreased in the Pinal Mountains from 160 acres in 2019 to just 50 acres in 2020. It is not unusual to see population increases at this location without a significant outbreak. Pupal parasitism from the previous year was commonly observed during larval surveys in 2020 (Figure 18), which may be contributing to decreases in observed damage.

New Mexico experienced a 99% decrease in DFTM activity from 1,560 acres in 2019 to only 20 acres in 2020. Activity on the Sandia Mountains of the Cibola NF subsided in 2020 with no new defoliation activity observed compared to 1,540 acres in 2019. The only suspected activity reported in New Mexico occurred on Navajo Tribal Lands, which increased from zero acres in 2019 to 20 acres in 2020. However, ground checks to confirm this damage have not been conducted.

Western Spruce Budworm

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

Western spruce budworm activity increased for a second year across the region, continuing an upward trend in damage attributed to this insect. Region-wide there was an over 55% increase in western spruce budworm activity, from 191,290 acres in 2019 to 297,270 in 2020 (Figure 19). Historically, most of the damage in the Southwestern Region occurs in New Mexico, which has a greater proportion of susceptible hosts. This held true in 2020, with New Mexico accounting for over 99% of the total damage in the region (Table 3). Most western spruce budworm-caused defoliation occurred in northern forests of the state, particularly on the Carson and Santa Fe NFs, and adjacent state and private lands, which accounted for 39%, 26%, and 28% of statewide damage, respectively. Damage increased on the Santa Fe NF (Figure 20) by 47,950 acres, on the Carson NF by 25,130 acres, and on state and private lands by 25,380 acres in 2020. The Carson NF had the most acres with damage in New Mexico, with 114,310 observed in 2020, a 28% increase from 89,190 acres in 2019. In addition, there was an increase in western spruce budworm activity on Jicarilla Apache Tribal Lands, with acres mapped growing from only 580 affected in 2019 to 5,640 in 2020. Elevated levels of defoliation have been observed in this area for at least four decades in both dry and wet mixed conifer forest stands, as well as some spruce-fir stands. Douglas-fir, white fir, and Engelmann spruce have all been observed with defoliation, but Douglas-fir has been the preferred host species. Twig dieback, top-kill, and tree mortality have resulted from continuous defoliation, and understory regeneration has been significantly affected in some stands.

In contrast, Arizona experienced an 85% decrease in acres affected by western spruce budworm in 2020, decreasing from 3,580 acres in 2019 to 530 in 2020 (Table 3). Most of the damage reported in Arizona continues to be observed north of the Grand Canyon on the Kaibab Plateau, especially around Pleasant Valley and De Motte Park. Many stands in the area occur in climax conditions which are conducive to this insect. A small area with suspected western spruce budworm activity was also mapped on the south side of the San Francisco Peaks, just west of Schultz Peak. The amount of observed damage from western spruce budworm fluctuates from year to year with weather and environmental conditions.

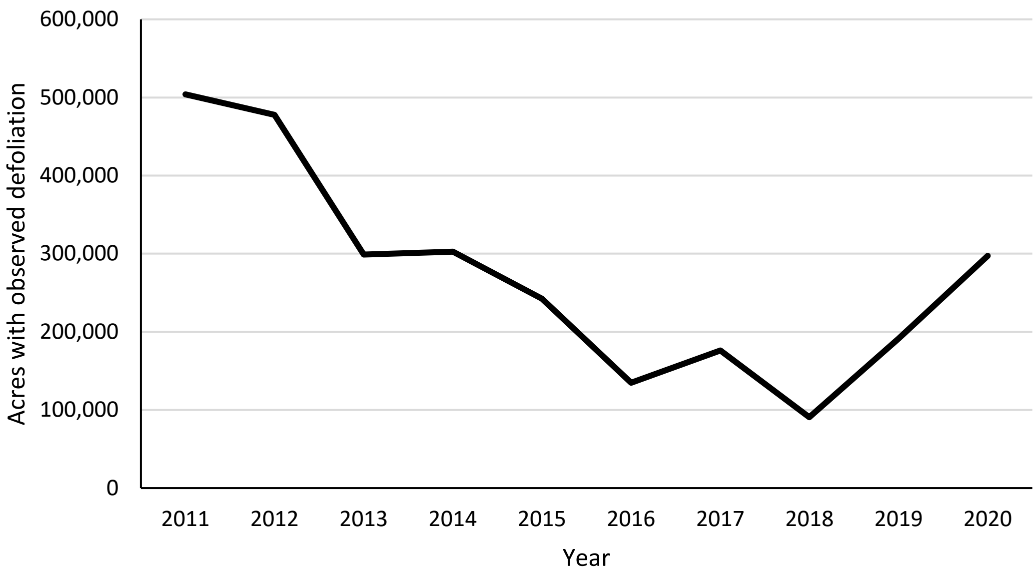

Figure 19. Defoliation attributed to western spruce budworm in the Southwestern Region over the last ten years.

Figure 20. Heavy defoliation of mixed conifer (trees with brown-yellow tinge) by western spruce budworm in the Jemez Mountains.

Janet’s Looper

Nepytia janetae
Hosts: Douglas-fir, white fir, occasionally spruce, corkbark fir, and five-needle pines

In New Mexico, mixed conifer defoliation was observed near Tesuque Creek from Hyde Park Road on the Santa Fe NF in January of 2018. Ground visits revealed the presence of Janet’s looper, an inchworm that defoliates several conifer species. Because it is a winter feeder, special flights were conducted in May of 2018 and 2019 to map the area affected and avoid confusion with defoliation caused by western spruce budworm, which is visible during the summer when the normal aerial surveys are conducted. There was no special flight in 2020, however damage attributed to Janet’s looper was still mapped on 2,620 acres in New Mexico, primarily on the Pecos Wilderness of the Santa Fe NF. This is a 53% decrease from total acres mapped in 2019. An additional 40 acres were mapped on state and private lands.

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 to and mortality of Engelmann spruce. Acres with current defoliation from this insect decreased for a second consecutive year after spiking in 2016 and 2018 (Figure 21). In 2020, 2,230 acres with defoliation attributed to spruce aphid were mapped compared to 8,100 acres in 2019. All of the damage was detected in Arizona, with most of the damage located in eastern Arizona around Mount Baldy on White Mountain Apache Tribal Lands and Greens Peak on the Apache-Sitgreaves NFs (Table 3, Figure 22). Acres with defoliation decreased most substantially on White Mountain Apache Tribal Lands, from 7,130 acres in 2019 to 1,430 in 2020. Although the number of acres with current damage is decreasing, severe mortality has resulted from consecutive years of damage. Spruce aphid damage was also mapped on the San Francisco Peaks, Coconino NF, where damage increased from five acres reported in 2019 to 10 acres in 2020. More information on spruce aphid in Arizona may be found in the “Other Entomology and Pathology Activities in 2020” section of this document under “Evaluating a Bio-Pesticide for Spruce Aphid Control”.

No spruce aphid activity was observed in New Mexico in 2020. 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. Damage has not been reported in New Mexico since then.

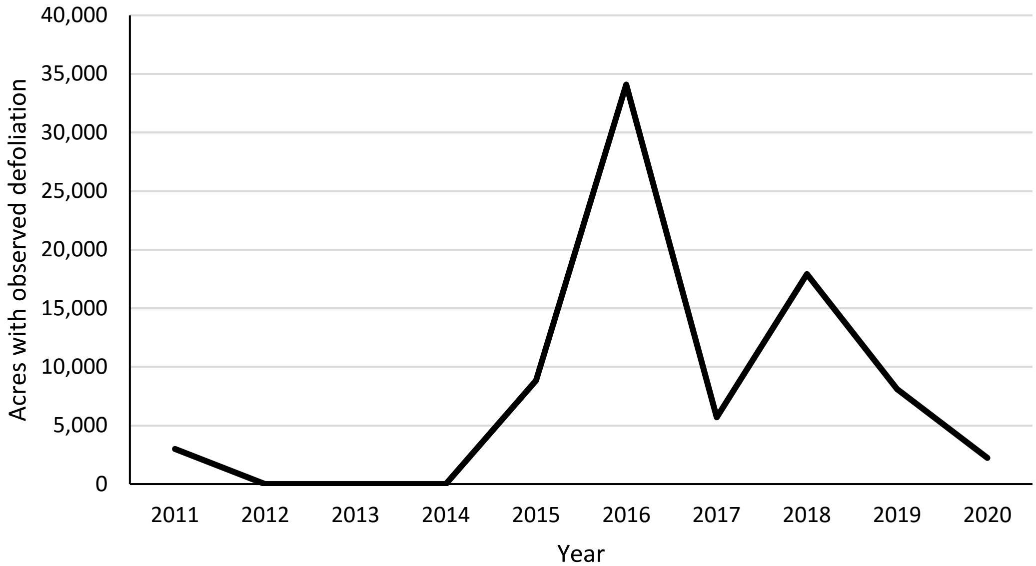

Figure 21. Defoliation attributed to spruce aphid in the Southwestern Region over the last ten years.

Figure 22. Spruce mortality occurring on Mount Baldy in eastern Arizona. New spruce beetle attacked trees have a lime green appearance compared to recent spruce aphid caused mortality that appears more red.

Miscellaneous Insects

Box elder tussock moth

Orgyia leuschneri

Hosts: Riparian species including, box elder, sycamore, ash, walnut, alder, apple, and other hardwoods.

Orgyia leuschneri is a lesser known, pale-yellow, tussock moth that can be observed feeding on riparian hosts, predominantly in canyons of the southwestern and western US (Figure 23). Outbreaks periodically occur in Arizona. This year, *O. leuschneri* was active around the Oak Creek Canyon Visitor Center near Indian Gardens and in Red Rock State Park.

Figure 23. *Orgyia leuschneri* larvae on its preferred host, box elder, in Oak Creek Canyon, Coconino National Forest.

Mesquite cutworms

Melipotis indomita
Hosts: Mesquite and palo verde

Large populations of mesquite cutworms were observed early this summer in the Verde Valley of Arizona (Figure 24). Complete defoliation of mesquite and palo verde trees was common. This damage was widespread in bosques around the Verde Valley, including Arcosanti, Rim Rock, and Cottonwood. The damage extended south towards the Agua Fria River north of Phoenix. Damage and high populations of larvae caused closure of campgrounds and cabins at Dead Horse State Park in June. Hosts re-foliated later that summer. The adult stage, known as miller moths, were also observed in larger abundance in New Mexico in 2020.

Figure 24. Mesquite cutworms after migrating to the forest floor to pupate, Dead Horse State Park, Cottonwood, Arizona.

Status of Major Diseases

Mistletoes

Dwarf Mistletoes

Arceuthobium spp.
Hosts: Various conifers

Figure 25. Female shoots of southwestern dwarf mistletoe with seeds on a ponderosa pine branch.

Dwarf mistletoes are among the most widespread and damaging forest pathogens (disease-causing organisms) in the Southwestern Region; over one-third of the ponderosa pine type (Figure 25) and up to one-half of the mixed conifer type has 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, like bark beetles or root disease. 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 three species primarily affecting ponderosa pine, pinyon pine, and Douglas-fir are found throughout most of their respective host ranges, while the other species have more limited distributions. In 2020, measurements continued on a permanent plot network established in 1991. This 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 2020".

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. Desert mistletoe (*P. californicum*), also leafless, can be abundant on mesquite, palo verde, and other leguminous shrubs and trees in desert woodlands. Big leaf mistletoe (*P. macrophyllum*) is ubiquitous throughout most riparian areas in the region where it infects many riparian hardwood species. Southwestern oak mistletoe (*P. coryae*) is common on oaks in lower elevations and in southern portions of the region. 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 recreation areas. In the Southwest, root diseases are usually more common in mixed conifer and spruce-fir forests than in ponderosa pine forests and can also be common in hardwood trees. 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 continues to persist on stumps and large roots 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 disease 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 26). 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, but *A. mellea* has been found in live oaks in southern Arizona. *Armillaria gallica* has also been identified in mixed conifer forests in Arizona. It is typically considered a saprophyte of dead trees. Previous surveys in mixed conifer forests on the North Kaibab RD, Kaibab NF found *Armillaria* spp. on about 30% of standing live trees. *Armillaria* samples from throughout the region are being identified to species by Dr. Jane Stewart at Colorado State University (CSU) as part of a west-wide Special Technology Development Program-funded project.

Figure 26. Mycelial fan associated with Armillaria root disease on a killed Douglas-fir seedling.

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 wet 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 corkbark fir and Engelmann spruce. *Heterobasidion irregulare* is found in ponderosa pine, and although it does not commonly cause disease in the Southwest, the pathogen is widely distributed throughout the region. Like *Armillaria* spp., *Heterobasidion* spp. are known as saprophytes or nutrient recyclers of dead woody material as well as pathogens and may thus persist 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 ponderosa pine, southwestern white pine, white fir, and spruce. Tomentosus root disease, caused by *Onnia tomentosa*, is found on spruce and Douglas-fir. 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 in Douglas-fir on Mescalero Apache Tribal Lands. Ganoderma root rot, caused by *Ganoderma applanatum*, is the primary root disease affecting aspen in the Southwest (Figure 27). The disease causes crown dieback, windthrow, and mortality, especially in older aspen stands; however, aspen of all ages are affected. More mesic aspen stands on the Carson NF seem to a have higher incidence compared to other forests in New Mexico. Monitoring is ongoing to assess damage caused by this disease through a network of semi-permanent plots located in Arizona and New Mexico.

Figure 27. Aspen failure caused by *G. applanatum*.

Stem Decays

Stem decays are common in older trees throughout the 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 in the Southwest is red belt fungus, *Fomitopsis schrenkii* (formerly *F. pinicola*), cause of a brown rot on various 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 (Figure 28); false tinder conk, *Phellinus tremulae*, on aspen; pouch fungus, *Cryptoporus volvatus*, a sap rot found on bark beetle-infested conifers; and *Phellinus everhartii* and *Inonotus dryophilus* on oak.

Figure 28. Fruiting body (conk) of the stem decay Indian paint fungus, *Echinodontium tinctorium*, on a white fir.

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)

Figure 29. Aecia emerging from a white pine blister rust canker on a southwestern white pine sapling.

White pine blister rust (WPBR), caused by *Cronartium ribicola*, is the only known exotic invasive forest disease in the region (Figure 29). In the Southwest, thousands of acres of mesic mixed conifer forest have severe WPBR infection, while 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.

In New Mexico, this disease continues to cause heavy damage to white pines on the Sacramento Mountains of southern New Mexico, where the disease has likely been established for over 40 years. 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 (Figure 30). In 2020, a new infection center was found on Mount Withington in the San Mateo Mountain Range (Socorro County, Magdalena RD). White pine blister rust was first documented on the Magdalena RD in 2019 in the Magdalena Mountains.

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 30). 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. In 2020, a new infection point was observed on Noble Mountain just north of Alpine, AZ. There are currently many areas where the disease is still absent in both states.

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 2020” section of this document under “White Pine Blister Rust Genetic Resistance”.

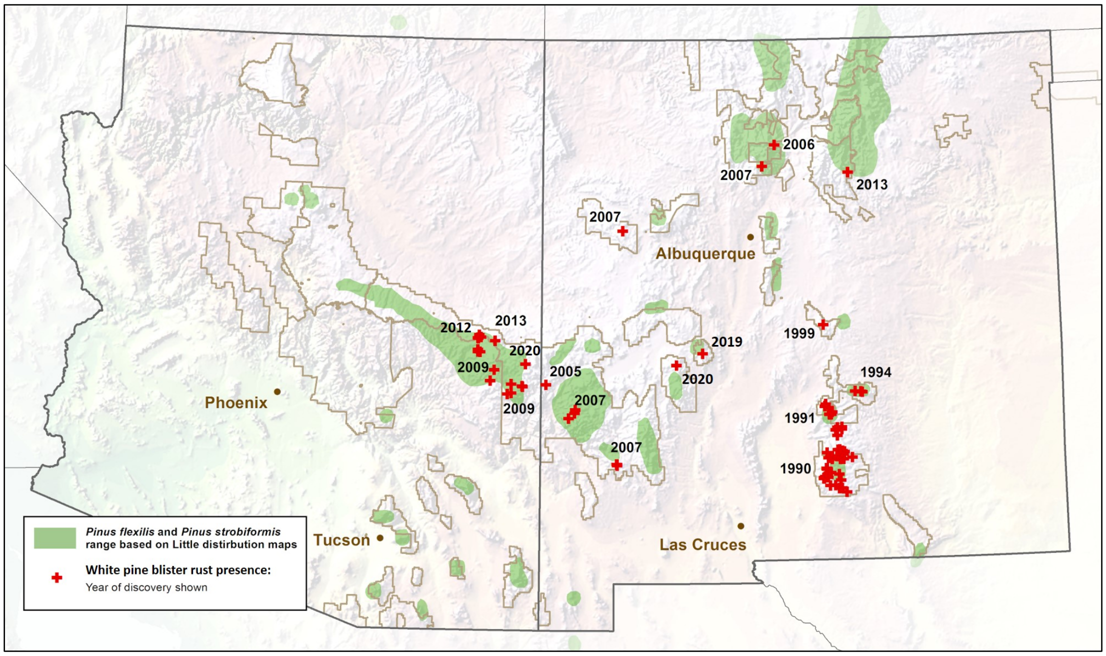

Figure 30. Distribution of known white pine blister rust infection centers within the Southwestern Region and the year in which they were discovered.

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 most of the Southwest (Figure 31). However, higher infestations rates 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; however, infection can result in top-kill, especially in spruce. Falling brooms or stem breakage at the point of infection present a hazard in developed recreation sites.

Figure 31. Witches' broom associated with fir broom rust on a young white fir.

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 region. The most common variety 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 infections 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. *Cytospora umbrina* or alder heat canker, was observed associated with alder die-back and mortality on Arizona alder (*Alnus oblongifolia*) in Oak Creek Canyon in 2020. Alder heat canker has been associated with large scale die-back and mortality of alder in Alaska, Colorado, and New Mexico. This pathogen has not been previously identified in Arizona or on Arizona alder.

Biscogniauxia meditteranea and an unidentified *Biscogniauxia* species have been observed affecting Emory oaks in southeastern Arizona on the Coronado National Forest (Figure 32). *Biscogniauxia* species are commonly associated with drought-stressed trees and can cause large cankers as well as decay in the sapwood of affected trees, leading to die-back or mortality. In Arizona, these pathogens have been associated with dieback and mortality of drought-stressed Emory oak and trees impacted by goldspotted oak borer. As the Southwestern Region continues to experience severe drought conditions, it is likely these *Biscogniauxia* species will become more apparent on the landscape. Work is underway to formally describe and document the currently undescribed species and to document the geographic distribution and host range of both species.

Figure 32. Cankers observed on Emory oaks; fruiting bodies may have white and/or black color depending on the stage of development

Foliar Diseases

Foliar diseases in the Southwest may occur in conifers (needle casts) or hardwoods. Fungal species causing these diseases generally overwinter in the previous year's leaf litter. Outbreaks are sporadic and highly dependent on favorable weather conditions. 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 commonly 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 Arizona, chronic white pine needle cast (*Lophodermella 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. In addition, sycamore anthracnose (*Apiognomonia 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 (Figure 33). In 2020, black leaf spot was recorded causing aspen defoliation on 220 acres on the Coconino NF (see Aspen Defoliation and Mortality).

Figure 33. Sycamore anthracnose affecting sycamores along Oak Creek. Note the white defoliated crowns of affected sycamores among the green full crowns of alder and other riparian species.

Abiotic Damage

Salt

De-icing salt use has contributed to increasing ponderosa pine mortality and discoloration along state highways over the last decade. Approximately 130 acres of salt damage were reported in 2020, up from 90 acres in 2019. The damage was observed along Interstate 40, Interstate 17, Highway 180, and Arizona State Route 89A in the Kaibab and Coconino NFs. About 40 acres of damage were mapped in New Mexico, down from 200 acres mapped in 2019. Damage was only mapped on the Carson NF. Damage has also been observed along county and city roadways as municipalities increase their use of de-icing salts. Use of dust abatement salt is also associated with mortality of ponderosa pine along dirt roads in rural housing areas.

Frost

Late season frost events can inflict significant damage to affected trees. Frost damage is infuenced by species, genetics, and site. It generally causes dieback of new succulent growth. This can cause significant stress, particularly when combined with other stressors such as drought and/or insect and disease activity. In New Mexico, a fairly large frost event was recorded in 2020, with 5,540 acres of frost damage mapped on oaks (primarily Gambel oak). About 63% of this damage occurred on the Carson NF (Figure 34A), including 3,200 acres on the Canjilon RD, as well as on neighboring state and private lands. Damage was also noted on the Santa Fe and

Cibola NFs and Mescalero Apache and Picuris Pueblo Tribal Lands. Although frost damage was not mapped via ADS flights in Arizona, it was reported affecting Gambel oak by forest personnel on the Tusayan and North Kaibab RDs of the Kaibab NF. Damage was particularly severe on the Tusayan RD, where it was observed causing mortality on younger stems. This is an added stress to the chronic ungulate browse that is suppressing regeneration and recruitment on this district. Frost damage was also observed on the Coronado NF affecting Engelmann spruce and white fir (Figure 34B).

Figure 34. A. Oak stands throughout the Carson National Forest were affected by a late frost (yellow-grey tinge to shorter vegetation) that caused dieback. B. Frost damage observed on Engelmann spruce on Mt. Graham, Coronado National Forest.

Drought

The Southwestern Region experienced severe drought conditions in 2020. Evidence of this acute stress was observed to some extent in all tree species but was particularly severe in ponderosa pine. Affected ponderosa pine exhibited slight yellowing of needles and some premature needle loss. Symptoms were most evident on dry ridges and upper slopes (Figure 35). New Mexico accounted for most of the drought stress mapped in ponderosa pine with 36,010 acres. Most of this was mapped on the Gila NF (15,560 acres) and state and private lands (14,680) east of the Sangre de Cristo Mountains in the vicinity of Las Vegas, NM. In northern Arizona, 14,300 acres of drought impacts were mapped, mainly in ponderosa pine forests. Most of this damage was mapped on the Coconino NF and concentrated just south of Flagstaff, Camp Navajo, and west of Mormon Lake. Delayed, late season mortality associated with drought stress was also observed across much of the region. This mortality was not recorded by ADS in 2020 due to the timing of the mortality. Drought stress may increase susceptibility to insects and diseases which do not affect vigorous trees. Drought may also act as a principle mortality agent.

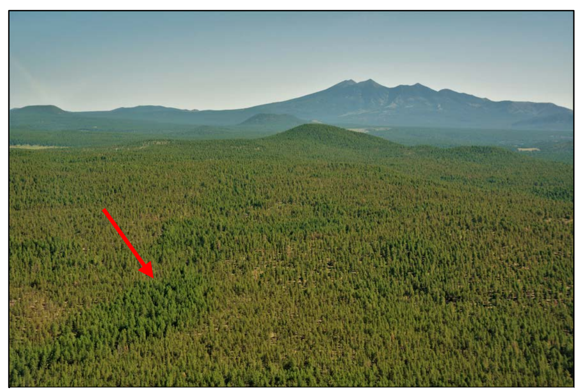

Figure 35. Drought stress observed on the Coconino National Forest. Note the yellowish color of affected ponderosa pine crowns and the green crowns of the trees located in the drainage (arrow).

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.

Table 4 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) can also 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 4. Major invasive species and diseases threatening national forests and grasslands in Arizona and New Mexico.

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

Buffelgrass

Buffelgrass (*Cenchrus ciliaris*) is the single greatest invasive threat to the Sonoran Desert in the Southwestern Region (Figure 36). The 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.

Figure 36. Buffelgrass (USDI National Park Service photo).

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 37). The 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.

Figure 37. Yellow bluestem panicle (courtesy photo by Billy Warrick; Soil, Crop and More Information).

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.

Saltcedar

One of the most widely distributed invasive species in the Southwestern Region is saltcedar (*Tamarix* spp.), which occurs as a shrub or a tree along many waterways and riparian areas. In 2001, several species of the tamarisk leaf beetle (*Diorhabda* spp.) from central Eurasia were released in western states as a host-specific biocontrol agent (Figure 38). Adult tamarisk leaf beetles and larvae both consume saltcedar foliage, which can damage or kill the plant over a number of years. Feeding by the beetle causes saltcedar leaves to dry out and turn brown while remaining on the stem; thus, crown discoloration is commonly seen in affected saltcedar stands.

Figure 38. Saltcedar leaf beetle (USDA APHIS photo by Robert Richard).

Since their release, different species of *Diorhabda* have migrated throughout much of Arizona and New Mexico. Further information on the *Diorhabda* beetle 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.).

FHP Programs and Information for Managing Invasive Species

Invasive Plant Grants

The FHP program of the Forest Service's State and Private Forestry (S&PF) branch provides grant funding for assistance with local management of invasive plants on state and private lands. In the Southwestern Region, funding for the invasive plant grant program is made through FHP grants to State Forester offices in Arizona and New Mexico, which are responsible for administering the grants. Funding from the FHP grant program has been used to treat buffelgrass, thistles, saltcedar, knapweeds, toadflaxes, and other invasive weeds found on noxious weed lists of the two states. Applicants for treatment projects involving invasive plants typically include Cooperative Weed Management Areas and Soil and Water Conservation Districts. Other organizations, such as non-governmental organizations, may also qualify if they are able to treat invasive plants on a cooperative basis. Priority for funding is given to applicants with proposed projects that will treat invasive plants that threaten forests and woodlands. Applicants should contact Willie Sommers (602-319-6818) in Arizona or Shannon Atencio (505-425-7472) in New Mexico for further information.

In addition to the FHP invasive plant grants, broad-scale projects for management of invasive species on state and private lands may be funded through FHP's Landscape-Scale Restoration program, which focuses on projects at a landscape level. For further information on S&PF grant programs for invasive plants, contact the state forestry offices located in Phoenix, Arizona (602-771-1400) or Santa Fe, New Mexico (505-476-3325).

Regional Website for Invasive Species

The Southwestern Region has a website for invasive species in the Southwest, which can be found at http://www.fs.usda.gov/main/r3/forest-grasslandhealth/invasivespecies. In addition to invasive plants, the website provides information on other invasive species including aquatic species, terrestrial animals, diseases affecting fish and wildlife, and insects and diseases affecting forest health. The booklet *Invasive Plants and Weeds of the National Forests and Grasslands in the Southwestern Region* is available on the website and can be used to identify invasive weed species in the Southwest. A series of field guides for managing many invasive and common weed species according to principles of integrated weed management are also available. The field guides are intended to be used by private landowners, governmental agencies, tribal nations, and other organizations for managing invasive weeds in the Southwestern Region.

Other Entomology and Pathology Activities in 2020

Forest Health Regional Training

The FHP staff provides annual training opportunities to resource managers that enhance forest health knowledge on insect and disease identification, effects, and management, as well as hazard tree identification and mitigation. In 2020, due to the COVID-19 pandemic, this training was held virtually. Insect and disease presentations were recorded and made available for those interested. Annually, the location of this training alternates between Arizona and New Mexico.

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 which may impact the health of the tree (Figure 39). These data, along with data from the plot network monitoring effects of fire on SWDM that was mentioned in this section of last year’s report, 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.*

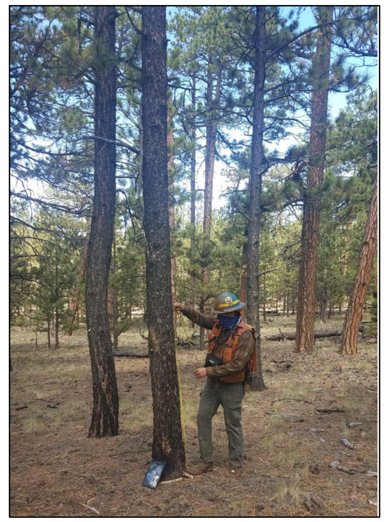

Figure 39. Data collection on PTIPS plot located on Mount Taylor in the Cibola National Forest.

White Pine Blister Rust Genetic Resistance

Figure 40. Mescalero Apache personnel climb a southwestern white pine with genetic resistance to white pine blister rust to collect scion.

In 2020, FHP continued work to sustain southwestern white 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 Drs. Kristen Waring of Northern Arizona University, Owen Burney of New Mexico State University, Richard Sniezko of the Dorena Genetic Resource Center (DGRC), and others. The second of two long-term southwestern white pine test sites, located on the Apache-Sitgreaves NFs, was planted in 2020 with 1,053 seedlings possessing varying levels of disease resistance or susceptibility. These are long-term, fenced test sites that will be used to evaluate the durability of various disease resistance mechanisms. The first site was established in 2017 on Mescalero Apache Tribal Lands in the Sacramento Mountains of New Mexico where 278 seedlings were planted. This planting experienced over 30% mortality in its first year, in part due to a major flooding event; additional plantings to replace killed seedlings and increase the diversity of genotypes being tested on the site will occur in 2021 or future years. In addition, FHP has collected scion from a number of new parent trees throughout the region over the last several years, all of which have shown some level of resistance to white pine blister rust, either via major gene resistance or quantitative resistance. In 2020, scion was collected from three trees on Mescalero Apache Tribal Lands in New Mexico (Figure 40) and one tree on the Apache-Sitgreaves NFs in Arizona. 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 which will be used to provide disease resistant seed for future reforestation efforts in the region. *For more information, contact Gregory Reynolds or Nicholas Wilhelmi.*

Fungal Diversity in Conifer Nurseries of the Southwest

Figure 41. Conifer production at a nursery sampled for fungal pathogens in the Southwestern Region.

Plant pathologists Greg Reynolds and Nicholas Wilhelmi (New Mexico and Arizona Zones, respectively) are collaborating with researchers John Dobbs and Jane Stewart from CSU, 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 western US. 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 occurred in 2020, with two tribal facilities and two state university facilities assessed (Figure 41). Thus far, we have isolated and identified *Fusarium graminearum, F. fujikuroi, F. lactis, F. commune, F. oxysporum, F. avaneceum, F. proliferatum, F. tricinctum, F. solani,* and *Phytophthora cryptogea* from diseased conifer seedlings growing in nurseries of the Southwestern Region. *For more information, contact Gregory Reynolds or Nicholas Wilhelmi.*

Aspen Monitoring in Northern Arizona

Forest Health Protection has been monitoring changes in Arizona's aspen via aerial survey and intensive site monitoring since the early 2000s. Monitoring plot networks have been installed on the Flagstaff (2008) and Mogollon Rim (2017) RDs, Coconino NF and the Williams RD, Kaibab NF (2012). In 2020, FHP continued collaboration with Dr. Kristen Waring and Connor Crouch (PhD student) of Northern Arizona University (NAU) to 1) assess the health of overstory, regeneration, and recruitment over a range of conditions; 2) assess the extent and severity of oystershell scale (OSS) across a range of conditions; 3) determine the relationship between current management practices for aspen sustainability and OSS-related impacts; and 4) model the impacts of climate change and management on long term aspen sustainability. This project is also in close collaboration with the national forests, working to build on past monitoring projects and plot networks. This collaboration has enabled significant expansion of current aspen monitoring plot networks. In 2020, a monitoring plot network (17 plots) was established on the Prescott NF, the first permanent aspen monitoring plot network on this forest. Permanent plots (16) were also installed to monitor regeneration, recruitment, and OSS following the Museum Fire on the Flagstaff RD, Coconino NF (Figure 42A). A total of 29 plots were resampled on the Williams RD, Kaibab NF; 25 of which followed an experimental clear fell treatment to treat OSS (pretreatment data was collected in 2018). The other four plots on the Williams RD were resampled to monitor an untreated, OSS infested exclosure. In addition, in 2020, a total of seven plots were installed on the Black Mesa RD, Apache-Sitgreaves NFs to monitor the impacts of prescribed fire on OSS and aspen regeneration in three large exclosures (Figure 42B). These aspen monitoring networks build upon previous monitoring networks in Arizona and will provide information on silvicultural treatments on OSS infestation. Currently there is no published information on the efficacy of silvicultural treatments related to OSS management. This much needed information will help to inform the forests in the management of this invasive insect. *For more information, contact Nicholas Wilhelmi or Amanda Grady.*

Figure 42. A) Severe browse on aspen regeneration following the Museum Fire on the Coconino National Forest. B) Aspen stem infected by oystershell scale on the Apache-Sitgreaves National Forests. Note the orange tendril-like *Cytospora* spp. fruiting bodies emerging.

Forest Health Unmanned Aircraft Systems Pilot Project

Figure 43. Ponderosa pine mortality observed on the Flagstaff RD during the 2020 aerial detection survey and documented using UAS.

On September 24th, the Arizona Zone completed a forest health mission using drone technology, also known as unmanned aircraft system (UAS). The pilot was John Yurcik from the USDA FS Flagstaff Dispatch Office. The UAS used was classified as a type three rotor wing. The model was a Parrot ANAFI Thermal which can take high resolution video and detect thermal infrared. There were two separate flights each lasting about 15 minutes. The UAS flight provided high definition photos and video of ponderosa mortality on the Coconino NF (Figure 43). The objective was to provide a safe, cost-effective means to photograph and video this forest health concern for the public and our clients to view in the 2020 Forest Health StoryMap summary. This summary highlights and reports on all insect and disease activity and forest damage recorded by aerial surveys across the Southwestern Region. The StoryMap can be viewed at: https://www.fs.usda.gov/detailfull/r3/forestgrasslandhealth/?cid=fseprd855188&width=full
For more information, contact Daniel DePinte.

Frye Fire, Coronado National Forest

Figure 44. ACE crews deploying MCH in a grid pattern in 2020.

The Frye Fire was started by lightning on June 7, 2017 and burned close to 48,500 acres on Mt. Graham in the Pinaleño Mountains on the Safford RD, Coronado NF, Arizona. This sky island is home to the endangered Mt. Graham red squirrel. Douglas-fir tree cones form a major portion of the squirrel's diet. Concerns about the potential for a Douglas-fir beetle outbreak prompted the Coronado NF, in conjunction with staff from Arizona FHP, to initiate a pheromone (MCH) project in 2018, designed to protect surviving Douglas-fir trees from bark beetle attacks in the remaining squirrel habitat. In addition, after we noted mountain pine beetle attacking fire-injured southwestern white pines during fall site visits in 2018, verbenone was included in the project. Both pheromones were deployed across ~500 acres of critical squirrel habitat in 2018 and 2019. In 2020, MCH was deployed across the same acreage as in 2019, but due to limited amount of verbenone packets, the verbenone was only deployed across 360 acres. The verbenone was deployed as single tree protection on SWWP greater than 18 inches DBH while the MCH was deployed in a grid pattern. In all years, the Coronado NF contracted crews with the American Conservation Experience (ACE) to deploy the pheromone packets (Figure 44). Surveys in September of 2020 continued to indicate that Douglas-fir and mountain pine beetle activity was minimal, both inside and outside of treated areas. Southwestern white pine was also being attacked by *Ips bonanseai*, usually in combination with mountain pine beetle. Due to limited activity we will discontinue pheromone protection in 2021. Ground surveys will continue as will monitoring using funnel traps. *For more information, contact Monica Gaylord.*

Ips verbenone study

Figure 45. Funnel trap with SPLAT deployed on carbboard squares.

In 2020, FHP AZ Zone, in conjunction with Drs. Chris Fettig and Jackson Audley at the Pacific Southwest Research Station (PSWRS) expanded on work started in 2019 to find an effective anti-aggregate for minimizing ponderosa pine tree mortality from *Ips pini*. In 2019, our study determined that verbenone in two different formulations, traditional plastic pouches and SPLAT formulation, decreased the attraction of *Ips pini* to funnel traps with pheromone aggregation lures (Figure 45). In 2020, we expanded this work to determine if adding acetophenone and non-host green leaf volatiles (GLV pouches [(E)-2-hexen-1-ol + (Z)-2-hexen-1-ol]) enhanced the efficacy of verbenone. In June of 2020 we installed fifty traps on the Kaibab NF. The area was near a thinning operation, and beetles were present throughout the area. We used a trapping bioassay consisting of five treatments: 1) aggregation pheromone only, 2) aggregation pheromone with verbenone dispensed from traditional plastic pouch, 3) aggregation pheromone with verbenone emitted from SPLAT formulation,

4) aggregation pheromone with verbenone dispensed from traditional plastic pouch and GLV and Acetophenone, and 5) aggregation pheromone with verbenone emitted from SPLAT formulation and GLV and Acetophenone. Traps were deployed from June to August of 2020. Collections are being sorted and analyzed at PSWRS. We anticipate submitting a publication in spring of 2021. *For more information, contact Monica Gaylord.*

Evaluating a Bio-pesticide for Spruce Aphid Control

Spruce aphid is an invasive and exotic pest that has been in outbreak status in the White Mountains of eastern Arizona for the past five years. During that time FHP, Arizona Zone, has partnered with Northern Arizona University and Montana Microbial, to evaluate a bio-pesticide (*Beauveria bassiana*) for control of spruce aphid, including in laboratory (2018), field (2019), and nursery settings (2020). In 2020, we tested low volume applications of BotaniGard® at the recommended label rate (high bracket), on 2-year-old potted blue spruce that were artificially infested with locally collected spruce aphids. Aphid mortality was monitored on sprayed and un-treated groups and cause of death from *Beauveria* was confirmed using aphid cadavers plated on *Beauveria* selective media. Laboratory and nursery studies find *B. bassiana* is highly effective against spruce aphid as applied in outdoor fall/winter conditions when the agent is present and actively feeding. *For more information, contact Amanda Grady.*

Figure 46. Nursery experiment to test efficacy of bio-pesticide, *Beauveria bassiana* against spruce aphid on artificially infested 2-year-old potted blue spruce at Northern Arizona University greenhouse facility.

Twig Beetle Special Project

Walnut twig beetle, *Pityophthorus juglandis*, is native to the Arizona and New Mexico, but has since been trapped and found attacking and killing walnut trees in many states in the US. This project is focused on: (1) collecting multiple species of walnut trees, and populations and lineages of the walnut twig beetle and *Geosmithia morbida* in the southwestern USA; (2) evaluating these native and ancestral populations to finely map the host and pest organism distributions; and (3) using statistical techniques to determine the degree of genetic exchange between invasive and non-invasive forms of the pests that may have facilitated their aggressiveness and the spread of TCD in the USA and Europe. The data from the first three objectives will be synthesized into an updated and higher accuracy host layer to improve the Risk Map and FHAAST Host Layer for these native walnut species. These steps should identify potentially resistant host material in the area of greatest genetic diversity of the pest organisms.

In FY 2020, we worked on data analyses and final project write up for all samples collected during the past four years. This required analyzing data using four different datasets from western US locations. Our group expects this publication to be drafted in 2021. *For more information, contact Andrew Graves.*

Pinyon Ips Special Project

Pinyon pine systems are outside their historic range of variation because of fire exclusion, grazing, and post-European settlement land use changes. Management agencies are attempting to restore some landscapes to approximate pre-European settlement conditions by implementing mechanical treatments (i.e., thinning). Such conditions are desired to optimize wildlife habitat and/or reduce fuel loading and concomitant wildfire behavior. However, slash from thinning treatments provides breeding opportunities for populations of the main bark beetle pest of pinyon pine, pinyon ips, which then infest residual trees. Empirical data has correlated tree- and stand-level conditions with infestation probability and density-based guidelines have been proposed for thinning treatments. Best management practices for the resulting slash, however, have not been examined for this cover type. The type and timing of slash treatments may substantially affect the probability of slash contributing to the loss of residuals pinyon pines by pinyon ips. We are conducting a three-year project to evaluate slash management practices in pinyon pine, including optimal timing of treatments. Specifically, we seek to understand bark beetle (pinyon ips) activity as a function of the timing and type of slash treatments. Results will provide FHP with empirical data to support recommendations for slash management in pinyon system thinning treatments and can be applied to all regions with pinyon type. *For more information, contact Andrew Graves.*

Biological Evaluations and Technical Assistance

Arizona Zone

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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.

Daniel DePinte (928) 556-2071

Daniel has been a forest health specialist for the Arizona Zone since 2015. Responsibilities include GIS program for Arizona, flight manager for aerial detection surveys in Arizona, data analysis, and field assistance. Daniel is also a tree climbing instructor and the regional coordinator/technical advisor for the Southwestern Region tree climbing program. Forest health interests include understanding the impacts of seed and cone insects on native conifers across the Southwestern Region.

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 forest defoliators to land managers across all land ownerships, providing entomological technical assistance on all non NFS lands, conducting insect and disease aerial detection surveys and monitoring native and exotic insects in the state. Technology transfer interests include bark beetle and defoliator semiochemical work, and monitoring forest pest with new detection methods.

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 land managers and hazard tree identification/mitigation training. Current interests include white pine blister rust resistance in southwestern white pine, dwarf mistletoe management, emerging diseases, and aspen monitoring.

New Mexico Zone

Andrew Graves (505) 842-3287

Andrew has been the Zone Leader for the New Mexico Zone since October 2019. 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.

Gregory Reynolds (505) 842-3288

Gregory 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. Gregory previously served as a plant pathologist (identifier) with the Animal and Plant Health Inspection Service in New Jersey.

Daniel Ryerson (505) 842-3285

Daniel has been a forest health and GIS specialist with the New Mexico Zone since 2003. Responsibilities include GIS program for New Mexico, aerial detection surveys, data analysis, technical support, and field assistance. Daniel is involved with the national insect and disease risk map project modeling future risk of forest mortality from insect and disease activity.

Steven Souder (505) 842-3286

Steven 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. Steven previously worked on fruit fly research with the Agricultural Research Service in Hawaii for over a decade.

Crystal Tischler (505) 842-3284

Crystal has been the Forest Health Coordinator with the New Mexico Zone since September 2008. She also serves as the regional Forest Health unit aviation officer. Responsibilities include aerial detection surveys, aviation safety and training coordination, and field assistance to staff. She is involved with educational outreach and implementation. Her previous work experience is in forest management, fuels reduction, timber sale administration, and community wildfire protection planning.

Regional Staff

Allen White (505) 842-3280

Allen has been the Regional coordinator for invasive species and pesticide-use since 2006. Duties include coordination and management of Regional programs: (1) National Forest System Invasive Species, (2) State & Private Pesticide-Use, and (3) State & Private Invasive Plant Grants. He also serves as the Region representative for the Biological Control of Invasive Plants (BCIP) grant program managed by the Forest Health Technology Enterprise Team (FHTET). Current work in the Region includes production of field guides and brochures for managing invasive plants and coordination of regional efforts to control yellow bluestem.

Appendix: Species Index

Table 5: 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 pseudotsugae*	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 casts	*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 sp.*
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	*Cerambycidae*	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 annually based on the USDA Agricultural Research Service's U.S. National Fungus Collections Database (https://nt.ars-grin.gov/fungaldatabases/fungushost/fungushost.cfm) and may not match the regional field guide.

** *D. barberi* was recently separated from *D. brevicomis* based on morphology (Valerio-Mendoza et al. 2019. Cryptic species discrimination in western pine beetle, *Dendroctonus brevicomis* LeConte (Curculionidae: Scolytinae), based on morphological characters and geometric morphometrics. Insects 10:377) and semiochemical behavior (Sullivan et al. 2021. Evidence for semiochemical divergence between sibling bark beetle species: *Dendroctonus brevicomis* and *Dendroctonus barberi*. Journal of Chemical Ecology 47:10–27). The common name of southwestern pine beetle is pending approval.