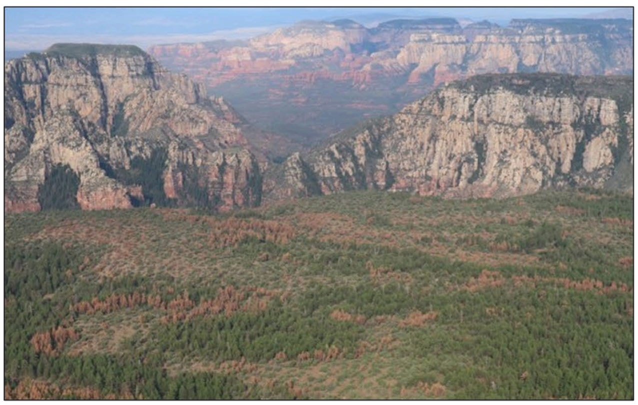
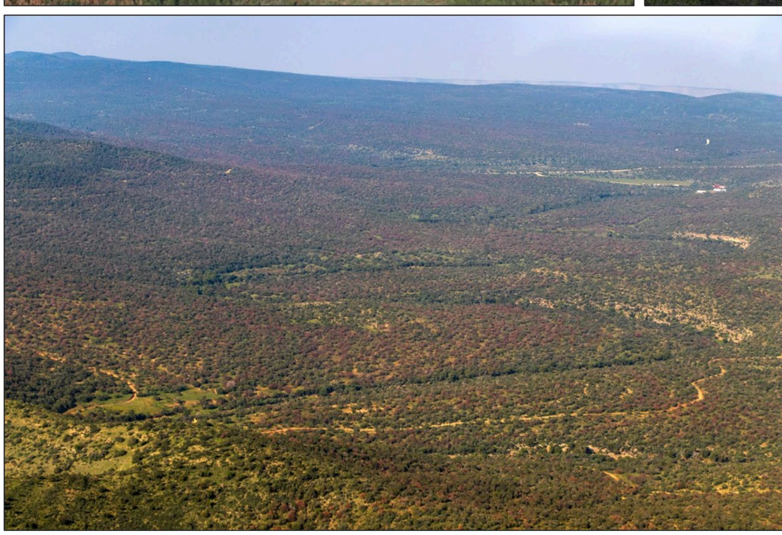
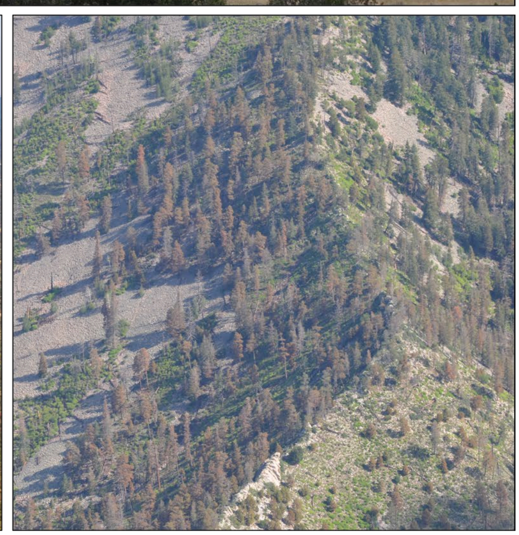
Forest Service
U.S. DEPARTMENT OF AGRICULTURE

Southwestern Region | PR-R3-16-21 | 2022

Forest Insect and Disease Conditions in the Southwestern Region, 2021



Cover photos: Clockwise from left: Ponderosa pine mortality on Coconino National Forest (NF); pinyon pine mortality on El Morro National Monument; red belt winter injury on Lincoln NF; and juniper dieback on the Guadalupe Mountains (Lincoln NF).

Forest Insect and Disease Conditions in the Southwestern Region, 2021

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Conditions in Brief

2021 Weather Summary for the Southwestern U.S.

Entering 2021, the majority of the Southwestern Region (Arizona and New Mexico) remained in exceptional drought status (highest level, D4) according to the United States Drought Monitor because of higher-than-normal temperatures and low precipitation that occurred throughout 2020. For the first half of 2021, the region continued to experience higher than normal temperatures (Figure 1), and the exceptional drought trend continued until average to above-average monsoonal moisture was experienced, particularly in the southern portions of Arizona and New Mexico (Figure 2). For the latter half of the year, parts of the Southwestern Region remained in severe and extreme drought status (D2 & D3), mainly in New Mexico. Weak to moderate La Niña conditions persisted through the end of the year resulting in continued drier than normal weather in the Southwestern Region heading into 2022.

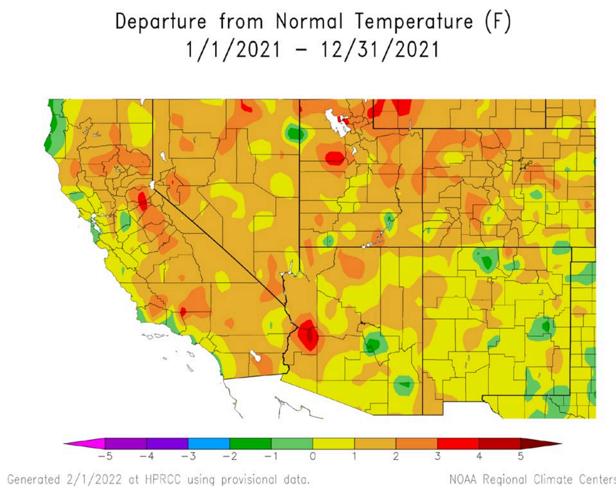

Figure 1. Departure in degrees (F) from normal temperature in the Southwestern U.S. for 2021 (Source: High Plains Regional Climate Center, https://hprcc.unl.edu).

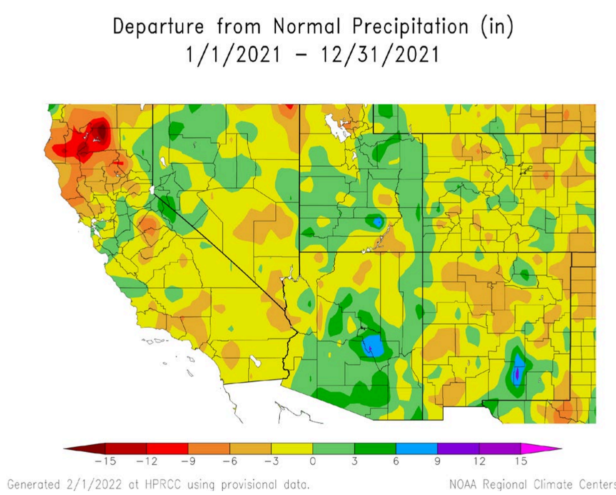

Figure 2. Departure from normal precipitation (inches) in the Southwestern U.S. for 2021 (Source: High Plains Regional Climate Center, https://hprcc.unl.edu).

Regional Forest Insect and Disease Summary

Aerial Survey Summary

In 2021, aerial detection surveys (ADS) covered approximately 24 million acres of the Southwestern Region. Aerial surveys primarily covered national forest land (54% of area surveyed), followed by tribal (23%), state and private (19%), and other federal lands (4%) (Table 1, Figure 3). An ArcGIS Online StoryMap summarizing the 2021 ADS results can be accessed at https://storymaps.arcgis.com/stories/b1df715fbb4a4d818459cbcfa4e96357.

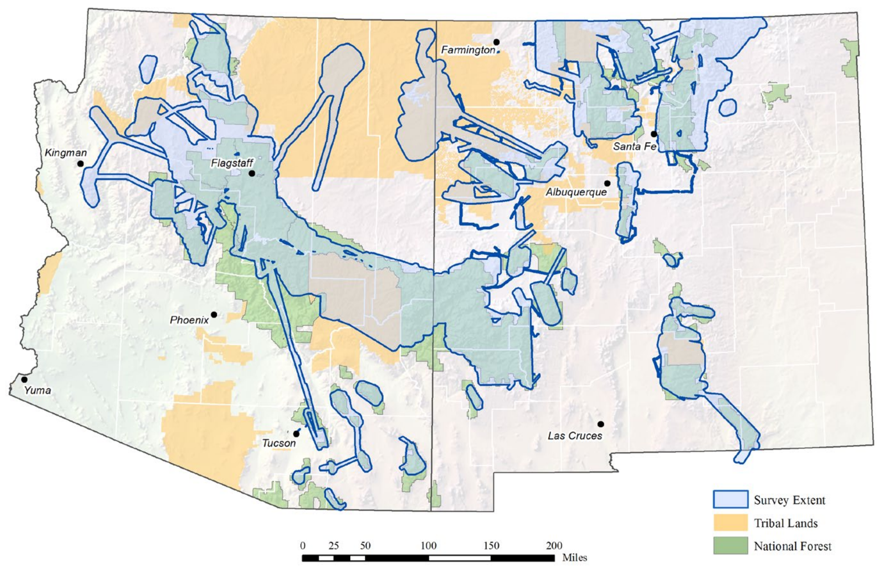

Figure 3. Areas surveyed during 2021 Aerial Detection Survey flights.

Table 1. Aerial Detection Survey acres flown in 2021 in the Southwestern Region.*

Land ownership	State	Forested	Woodland	Total
National Forest Lands	AZ	3,120,700	3,073,500	6,194,200
Bureau of Land Management	AZ	22,600	133,200	155,800
Department of Defense	AZ	29,200	14,500	43,600
National Park Service	AZ	266,600	400,600	667,200
Tribal	AZ	1,294,100	2,391,600	3,685,700
State and Private	AZ	224,100	1,028,700	1,252,800
Arizona Total		**4,918,000**	**6,843,300**	**11,761,400**
National Forest Lands	NM	4,380,000	2,398,900	6,779,000
Bureau of Land Management	NM	47,600	364,900	412,600
Bureau of Reclamation	NM	1,800	9,300	11,100
Department of Defense	NM	100	800	900
Department of Energy	NM	9,000	11,000	20,000
National Park Service	NM	87,800	19,100	106,900
Tribal	NM	1,388,100	771,700	1,723,100
State and Private	NM	1,974,100	1,265,000	3,239,000
New Mexico Total		**7,451,800**	**4,840,700**	**12,292,600**

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

Bark Beetle Summary

Regionwide, acres with mortality attributed to bark beetles increased to levels more than five times greater than those observed in 2020. Tree mortality attributed to bark beetles was mapped on 772,940 acres in 2021 compared to 142,060 acres in 2020. Acreage with mortality increased for all bark beetle species. The overall increase in bark beetle-related mortality as reported by ADS, was primarily due to the exceptional drought conditions and lack of monsoonal moisture from 2020 that led to stressful conditions across the region heading into year 2021.

Bark beetle-related ponderosa pine mortality increased dramatically across Arizona (Table 2). Acres with ponderosa pine mortality increased from 62,570 acres in 2020 to 427,010 acres in 2021. Ponderosa pine bark beetles were the most prevalent mortality agent mapped in Arizona. The Coconino and Kaibab National Forests (NF) saw the largest increases in ponderosa pine mortality, with acres affected increasing on the Coconino NF from 32,730 acres in 2020 to 165,660 acres in 2021 and from 11,340 acres in 2020 to 59,180 acres in 2021 on the Kaibab NF. The Coconino and Kaibab NFs accounted for 53% of acres mapped with ponderosa mortality in Arizona. Pinyon mortality increased overall throughout the state from 10,820 acres with mortality in 2020 to 68,940 acres in 2021. The two exceptions with decreased acres with pinyon mortality were Canyon de Chelly National Monument with 1,910 acres in 2020 dropping to 20 acres in 2021 and Navajo Nation with 8,580 acres in 2020 and 8,010 acres in 2021. Most pinyon mortality, about 47%, was mapped on the Kaibab NF surrounding Grand Canyon National Park.

Figure 4. Ponderosa pine mortality, reddish-brown colored trees, from bark beetles on the Coconino NF, Arizona.

Ponderosa pine bark beetles represented most of the bark beetle-related mortality in New Mexico. Ponderosa pine acres with mortality mapped in New Mexico increased from 12,580 acres in 2020 to 116,080 acres in 2021 (Table 2). Most of the ponderosa mortality was observed on the Gila NF, which accounted for 67% of total mapped ponderosa mortality (Figure 4). Pinyon mortality also increased dramatically with acres affected rising from 3,650 acres in 2020 to 66,830 acres in 2021. Most pinyon mortality was observed on Tribal Lands across New Mexico, which accounted for 39% of total acres. This was followed by State and Private land accounting for 27% of the pinyon acres of mortality. Spruce beetle activity slightly increased in the region, and most of this activity occurred in New Mexico. Acres with spruce beetle-related mortality decreased in Arizona from 2,240 acres with mortality in 2020 to 530 acres in 2021. New Mexico observed a slight increase with 31,020 acres with mortality in 2020 rising to 34,400 acres in 2021. The increase was primarily observed on the Carson NF which nearly doubled in acres with mortality from 7,910 acres in 2020 to 14,740 acres in 2021. Spruce beetle was primarily mapped on the Santa Fe (52%) and Carson (42%) NFs.

Table 2. Bark beetle[1] incidence by ownership (acres) from aerial detection surveys in 2021 in Arizona and New Mexico[2].

Owner[3]	Ponderosa pine bark beetles[4]	Pinyon ips	Douglas-fir beetle	Spruce beetle	Western balsam bark beetle	Fir engraver
Apache-Sitgreaves National Forest	36,590	7,190	30	90	200	690
Coconino National Forest	165,660	250	830	100	180	2,860
Coronado National Forest		50	180		100	1,170
Kaibab National Forest	59,180	32,380	1,240	260	930	570
Prescott National Forest	29,430	1,480				580
Tonto National Forest	29,390	2,100				310
Bureau of Land Management	4,380	2,300				
Department of Defense	3,180					
Canyon de Chelly National Monument	60	20				
Grand Canyon National Park	9,950	2,140	1,440		1,550	960
Lake Mead National Recreation Area		120				
Sunset Crater National Monument	< 5					
Walnut Canyon National Monument	120	< 5				
Havasupai Tribal		2,510				
Hopi Tribal	20	40				
Hualapai Tribal	4,250	5,970				
Navajo Nation	2,030	8,010	1,220		660	
San Carlos Apache	28,520	40				
White Mtn Apache	38,230	120	160	70	1,400	4.690
Other Tribal	20					
State & Private	16,015	4,225	< 5	10		110
Arizona Total	427,010	68,940	5,090	530	5,010	11,920
Carson National Forest	6,180	530	5,530	14,740	80	130
Cibola National Forest	6,840	4,610	2,190	< 5	80	1,500
Gila National Forest	77,220	2,200	2,640		< 5	20
Lincoln National Forest	5,450	1,090	290			<5
Santa Fe National Forest	3,170	640	12,730	18,140	180	860
Bureau of Land Management	260	13,500	< 5			
Department of Energy	40	< 5	< 5			
Bandelier National Monument	20	< 5	< 5			
El Malpais National Monument	< 5	< 5				
El Morro National Monument	< 5	50				
Pecos National Historic Park	< 5	< 5				
Valles Caldera National Preserve	350		260			20
Acoma Pueblo	70	10	< 5			
Isleta Pueblo	490	< 5	70			
Jemez Pueblo	40	50	30			
Jicarilla Apache Tribal	1,020	5.960	50	130		< 5
Laguna Pueblo	480	< 5	< 5			
Mescalero Apache Tribal	2,150	20	100	< 5	200	< 5
Navajo Nation	250	15,830	1,100		220	
Picuris Pueblo	20	< 5	60			120
Ramah Tribal		2,100				
Santa Clara Pueblo	10					<
Taos Pueblo	< 5		1,210	< 5	< 5	
Zia Pueblo	< 5	40				
Zuni Pueblo	10	2,340				
State & Private	12,010	17,860	2,000	1,390	10	325
New Mexico Total	116,080	66,830	28,270	34,400	770	2,950
Grand Total	543,090	135,780	33,360	34,930	5,780	14,880

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

Defoliation Summary

Defoliation from insects and diseases (including agents not included in Table 3) decreased slightly across the region from 426,880 acres in 2020 to 417,070 in 2021 (Table 3). Most acres with defoliation (85%) were detected in New Mexico, largely on State and Private land (44%) and attributed to western spruce budworm (mixed conifer, spruce/fir) and ponderosa pine needleminer activity. Detectable western spruce budworm damage decreased from 297,270 acres in 2020 to 227,740 acres in 2021. Damage from ponderosa pine needleminer was mapped exclusively in New Mexico where 100,000 acres with defoliation were observed on State and Private land (88%) and the Carson NF (12%). Aspen damage, which includes defoliation, dieback, and mortality, decreased across the region from 69,120 acres in 2020 to 20,000 acres in 2021 (Figure 5). Most of the observed damage occurred in New Mexico (77%) on the Santa Fe NF. In Arizona, much of the damage was observed on Navajo Nation Tribal Lands and on the Kaibab NF (Table 3). Acres with aspen dieback attributed to the emerging pest oystershell scale were documented in Arizona in 2021. This is the first year that these data have been incorporated into our national Insect and Disease Survey (IDS) data set. Ground surveys documented more than 250 acres within high value ungulate exclosures on National Forest System Lands (NFS) in northern Arizona.

Figure 5. Aspen defoliation observed in New Mexico.

Damage from sap sucking insects was particularly prominent in Arizona in 2021. Active damage agents include pinyon needle scale, Prescott scale, oystershell scale, and spruce aphid. Observed acres with pinyon needle scale damage nearly quadrupled across the region from 13,700 acres in 2020 to 53,740 acres in 2021 (Table 3). Most of this damage (75%) was detected in Arizona where acres with damage increased from 12,860 in 2020 to 40,050 in 2021. Pinyon needle scale damage accounted for nearly 64% of Arizona's total acres with defoliation. Pinyon needle scale damage was primarily observed on the Kaibab and Prescott NFs and Hualapai Tribal Lands. In New Mexico, acres with pinyon needle scale damage increased from 840 in 2020 to 13,700 in 2021, mostly on State and Private land (77%). Drought conditions that persisted through most of 2020 may have contributed to the amount of observable pinyon needle scale damage detected across the region in 2021.

Drought also contributed to increased observations of Prescott scale in eastern Arizona where outbreaks have occurred historically. A total of 1,350 acres with branch dieback were observed aerially and ground validated at several locations, primarily on White Mountain Apache Tribal Lands (1,300 acres). A minor amount was also detected on neighboring Apache-Sitgreaves NFs (50 acres).

Defoliation from spruce aphid decreased in Arizona from 2,230 acres in 2020 to 310 in 2021 (Table 3). Douglas-fir tussock moth and Janet's Looper activity was not observed in the region in 2021.

Table 3. Defoliation[1] and aspen damage incidence by ownership (acres) from aerial detection surveys in 2021 in Arizona and New Mexico[2].

Owner[3]	Western spruce budworm	Aspen[4] damage	Needle-miner	Pinyon needle scale	Sawfly-ponderosa	Spruce aphid
Apache-Sitgreaves National Forests	680	400		260		130
Coconino National Forest	430	920		3,280	10	50
Coronado National Forest						
Kaibab National Forest	640	1,190		2,140		
Prescott National Forest		< 5		9,090		
Tonto National Forest				9,030		
Bureau of Land Management				20		
Grand Canyon National Park	100	180		350		
Saguaro National Monument		10				
Havasupai Indian Res.				290		
Hopi Indian Res.						
Hualapai Indian Res.				7,410		
Kaibab Indian Res.						
Navajo Indian Res.	980	1400		100		
San Carlos Indian Res.				1,060		
White Mtn Apache Indian Res.	1,710	320		3,450		130
Yavapai Prescott Indian Res.				20		
Yavapai Tonto Apache Res.				60		
State & Private		380		3,500		
Arizona Total	**4,530**	**4,800**		**40,050**	**10**	**310**
Carson National Forest	72,090	1730	11,840			
Cibola National Forest	2,190	1210		1,280		
Gila National Forest		130			140	
Lincoln National Forest	6,530	550		370		
Santa Fe National Forest	43,300	7230				
Bureau of Land Management	300		20	50		
Department of Energy		< 5				
Valles Caldera National Preserve	3,490					
Jicarilla Apache Tribal	6,780	40				
Laguna Pueblo	10	40				
Mescalero Apache Tribal	< 5	120		1,200		
Navajo Nation	2,580	1150		210		
Picuris Pueblo		< 5				
Santa Clara Pueblo		10				
Taos Pueblo	5,640	70				
State & Private	80,280	3,220	88,140	10,580	910	
New Mexico Total	**223,200**	**15,490**	**100,000**	**13,700**	**1,050**	
Grand Total	**227,740**	**20,290**	**100,000**	**53,740**	**1,060**	**310**

[1]Only major defoliator agents shown. Less commonly detected agents or those with lesser activity may not be represented in the table.
[2]Values rounded to the nearest 10, sum of individual values may differ from totals due to rounding and multiple agents occurring in the same location; a blank cell indicates no damage was observed.
[3]Values based on landownership, thus any inholdings are summarized with their ownership category.
[4]Aspen damage includes a combination of insect defoliation and other biotic and abiotic factors causing aspen decline 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 (Arizona 1,873,000 acres and New Mexico 2,073,000 acres across all ownerships) are based on historical records, which indicate that over one-third of the ponderosa pine acreage and about one-half of the mixed conifer acreage have some level of infection. Recent roadside surveys showed similar affected area in ponderosa pine compared with these historical records.

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

Abiotic Summary

Severe to exceptional drought conditions persisted in the Southwest until significant monsoon moisture reduced drought severity across the region (Figure 6). Due to these conditions, abiotic damage was significantly elevated across the Southwestern Region in 2021 (Table 4). Impacts were documented from woodlands to high elevation forests. Drought-induced discoloration of all conifer spp. (primarily ponderosa and pinyon) was mapped on 142,630 acres regionwide. The most significant event observed this year was widespread drought-induced dieback in juniper on over 330,000 acres in Arizona. A large red belt winter injury event occurred in southern New Mexico and affected nearly 7,000 acres across Carrizo Mountain, Sierra Blanca, and the Capitan Mountains of the Lincoln National Forest and Mescalero Apache Tribal Lands. Additionally, a major hail damage event was mapped on the Santa Fe NF affecting 3,400 acres.

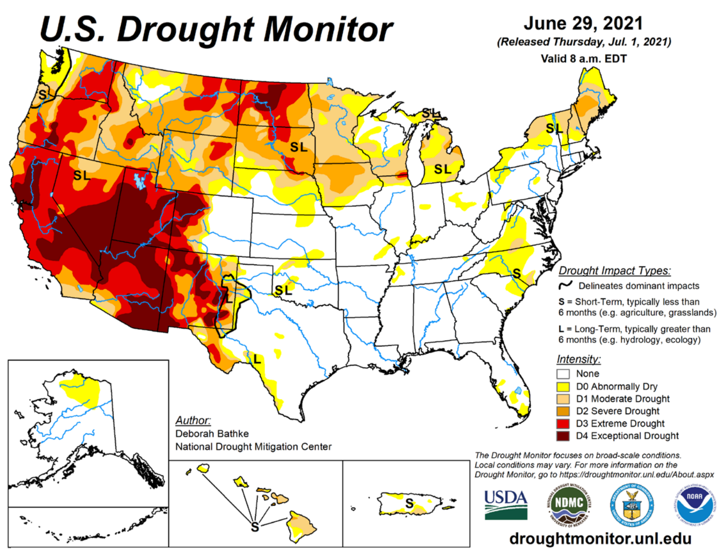

Figure 6. U.S. Drought Monitor shows severe to extreme drought conditions across the Southwest at the start of the aerial detection survey season.

Table 4. Abiotic damage[1] incidence by ownership (acres) from aerial detection surveys in 2021 in Arizona and New Mexico[2].

Owner[3]	Drought discolor all spp.	Juniper dieback	Drought & GSOB discolor	Ponderosa[4] branch flagging	Juniper[5] branch flagging	Winter injury all spp.	Ponderosa road salt
Apache-Sitgreaves NFs	17,220	2,040	20	1,180			
Coconino National Forest	11,780	78,700		3,000			190
Coronado National Forest	6,420	6,570	2,680				
Kaibab National Forest	8,380	68,320		1,260			30
Prescott National Forest	1,920	32,340	60	640	1,690		
Tonto National Forest	3,000	4,770		260			10
Bureau of Land Mgmt	3,080	9,150					
Department of Defense	1,360	300		140			
Grand Canyon Nat'l Park	480	1,630					
Lake Mead NRA		430					
Saguaro Nat'l Park	820	260	20				
Wupatki Nat'l Monument		1,700					
Havasupai Indian Res.		450					
Hopi Indian Res.		900					
Hualapai Indian Res.	1,310	6,090					
Navajo Indian Res.	2,510	20,330	50				
San Carlos Indian Res.	5,460	2,060					
White Mtn Apache IR	1,740	3,440		4,710			
Yavapai Prescott IR		10					
State & Private	3,980	94,610	280	60			40
Arizona Total	**65,480**	**334,100**	**3,110**	**11,250**	**1,690**		**270**
Carson National Forest	26,110		620				
Cibola National Forest	10,940		150				
Gila National Forest	23,740	40	10				
Lincoln National Forest	2,800	21,380				5,810	
Santa Fe National Forest	9,610		100				
Bureau of Land Mgmt	210	140					
Department of Energy							10
Bandelier Nat'l Monument							10
Carlsbad Caverns NP		30					
Valles Caldera NP	150						
Acoma Pueblo	490						
Isleta Pueblo	90						
Jemez Pueblo	90						
Jicarilla Apache Tribal	640			300			
Laguna Pueblo	30						
Mescalero Apache Tribal	670			10		820	120
Navajo Nation	540						80
Taos Pueblo	1,040						
Zia Pueblo					30		
State & Private	46,840	2,130	190			210	20
New Mexico Total	**77,150**	**23,720**	**1,070**	**310**	**30**	**6,840**	**220**
Grand Total	**142,630**	**357,820**	**4,180**	**11,560**	**1,720**	**6,840**	**490**

[1]Only major abiotic damage shown. Less commonly detected damage or those with lesser activity may not be represented in the table.
[2]Values rounded to the nearest 10, sum of individual values may differ from totals due to rounding and multiple agents occurring in the same location; a blank cell indicates no damage was observed.
[3]Values based on landownership, thus any inholdings are summarized with their ownership category.
[4]Ponderosa branch flagging includes acres with damage caused by Prescott scale and general branch flagging with no insect damage.
[5]Juniper branch flagging includes acres with damage from the juniper twig pruner and general branch flagging with no insect damage.

Status of Major Insects

Bark Beetles

Overall totals of acres with tree mortality attributed to bark beetles increased across the region in 2021 (Table 2). Acres with pinyon mortality increased throughout the region with most of the damage located on the Kaibab NF (24%) and Navajo Nation Tribal Lands in both Arizona (6%) and New Mexico (12%). In addition, Bureau of Land Management lands in both states accounted for another 12% of pinyon mortality. Ponderosa mortality increased in Arizona and New Mexico and was mapped on 543,090 acres. Much of the mortality was mapped on the Coconino NF (31%) in Arizona and the Gila NF (14%) in New Mexico. Fir engraver activity increased across the region, mostly in Arizona, with damage located there on White Mountain Apache Tribal Lands (32%) and the Coconino NF (19%) and in New Mexico on Cibola NF (10%). Douglas-fir beetle activity more than doubled with most of the mortality occurring in New Mexico. Locations with the highest proportion of mortality were on the Kaibab NF (4%), Grand Canyon National Park (4%), and Navajo Nation (4%) in Arizona, and on the Santa Fe (38%) and Carson (17%) NFs in New Mexico. Western balsam bark beetle activity increased regionwide with most of the mortality in Arizona. Locations with the highest mortality were observed on Grand Canyon National Park (27%) and White Mountain Apache Tribal Lands (24%) in Arizona and Mescalero Apache (3%) and Navajo Nation Tribal Lands (4%) in New Mexico. Spruce beetle activity increased slightly across the region, 98% of which was in New Mexico, largely on the Santa Fe (42%) and Carson (52%) NFs. 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 regionwide increase in bark beetle-attributed mortality (Figure 7). Total area with bark beetle mortality observed in the pinyon-juniper forest type increased more than nine times, intensifying from 14,470 acres in 2020 to 135,780 in 2021. The damage occurred nearly equally in Arizona (51%) and New Mexico (49%). Juniper dieback due to drought was among the most dramatic damage events in the region in 2021, rising from 735 acres in 2020 to 357,820 acres in 2021. The damage occurring predominantly in Arizona (93%) on the Coconino and Kaibab NFs, and State and Private lands. There were no mapped areas in New Mexico in 2020; however in 2021, 21,300 acres of juniper dieback were mapped with the majority observed on the Guadalupe Mountains, Lincoln NF.

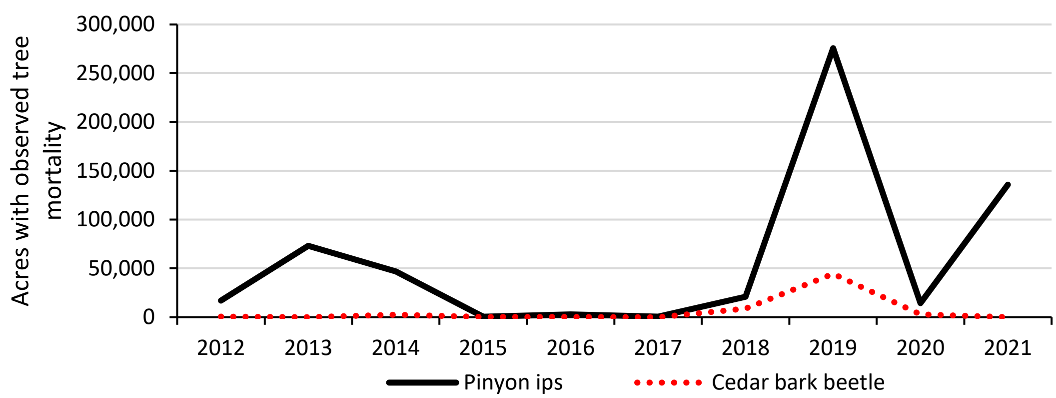

Figure 7. Pinyon-juniper mortality associated with ips and cedar bark beetles in the Southwestern Region for the last ten years.

Pinyon Ips

Ips confusus
Host: Pinyon pine

In 2021, acres with pinyon mortality increased over nine-fold from 14,470 acres in 2020 to 135,780 acres (Table 2, Figure 7). Special survey flights were conducted due to early season observed mortality resulting in a larger area of pinyon-juniper woodland coverage than in typical years. Most pinyon mortality (51%) occurred in Arizona, where acres with mortality increased from 10,820 in 2020 to 68,940 in 2021. New Mexico accounted for nearly half of the overall mortality (49%) as mapped acres with pinyon mortality rose from 3,650 acres in 2020 to 66,830 in 2021. The Kaibab NF (24%) and Navajo Nation Tribal Lands (17%) accounted for the majority of all the pinyon mortality in both Arizona and New Mexico (Figure 8). Acres with pinyon mortality mapped on the Kaibab NF rose from 50 acres in 2020 to 32,380 acres in 2021. Pinyon mortality is occurring at the stand level across the landscape in this location. Navajo Nation Tribal Lands in Arizona, though representing a large proportion of pinyon mortality in the region, decreased by about 7% in 2021, dropping from 8,580 acres in 2020 to 8,010 in 2021. In New Mexico, pinyon mortality on Navajo Nation Tribal Lands increased from 2,900 acres in 2020 to 15,830 acres in 2021. State and Private land across the region rose from 420 acres in 2020 to 22,090 acres in 2021.

Figure 8. Pinyon pine mortality caused by ips beetles observed on Ramah Navajo Tribal Lands, New Mexico

Cedar Bark Beetles

Phloeosinus spp.
Host: Junipers and Arizona cypress

Juniper mortality is generally linked to cedar bark beetle activity in the Southwest. However, drought induced cavitation was the main factor influencing widespread juniper dieback documented during the 2021 survey season. Therefore, cedar bark beetle activity was not associated with juniper dieback during the 2021 aerial surveys, dropping from 2,980 acres in 2020 to zero acres recorded in 2021. Limited cedar bark beetle activity was observed during ground surveys in northern Arizona and during site evaluations across the Four Corners region. Additionally, Lincoln NF and other NFS personnel visited the Guadalupe Mountains in early 2022 and did observe cedar bark beetles playing a role in the dieback occurring there. For more information see the Abiotic section.

Juniper twig pruner

Styloxus bicolor
Host: Junipers

The juniper twig pruner is a native longhorn beetle that causes tip dieback during dry periods and represents another symptom of drought impacts in the woodlands of Arizona. Significant stand level damage was mapped across 1,690 acres on the Prescott NF. We do not commonly map this type of damage, however branch flagging and tip dieback were major damage types documented in Arizona during the 2021 ADS flights.

Ponderosa Pine Forest Type

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

There was a drought driven increase in ponderosa pine mortality in 2021, with 543,090 acres with mortality mapped across the region compared to 75,160 in 2020 (Figure 9). The majority (79%) occurred in Arizona with 427,010 acres. Most of the mortality mapped in Arizona was located on the Coconino NF, which saw ponderosa pine mortality surge five-fold, increasing from 32,730 acres in 2020 to 165,660 in 2021. Mortality on the Coconino NF was evenly distributed across the Flagstaff and Mogollon Rim Ranger Districts (RD). The Kaibab NF also saw an increase in ponderosa pine mortality, increasing from 11,340 acres in 2020 to 59,180 in 2021; most of the mortality was mapped on the North Kaibab RD. Significant acres with ponderosa pine discoloration caused by drought stress were mapped in these locations in 2020, and in 2021 these areas progressed to large groups of ponderosa pine mortality scattered across the landscape. Ground surveys found numerous beetle species, including several species of engraver beetles, southwestern pine beetle, roundheaded pine beetle, and red turpentine beetle.

In New Mexico, ponderosa pine acres with mortality increased from 12,580 in 2020 to 116,080 in 2021 (Figure 9). Most of the mortality in New Mexico (67%) was located on the Gila NF on the western portion of the Pinos Altos Range (Figure 10). State and Private land had the second highest proportion of mortality in New Mexico (10%).

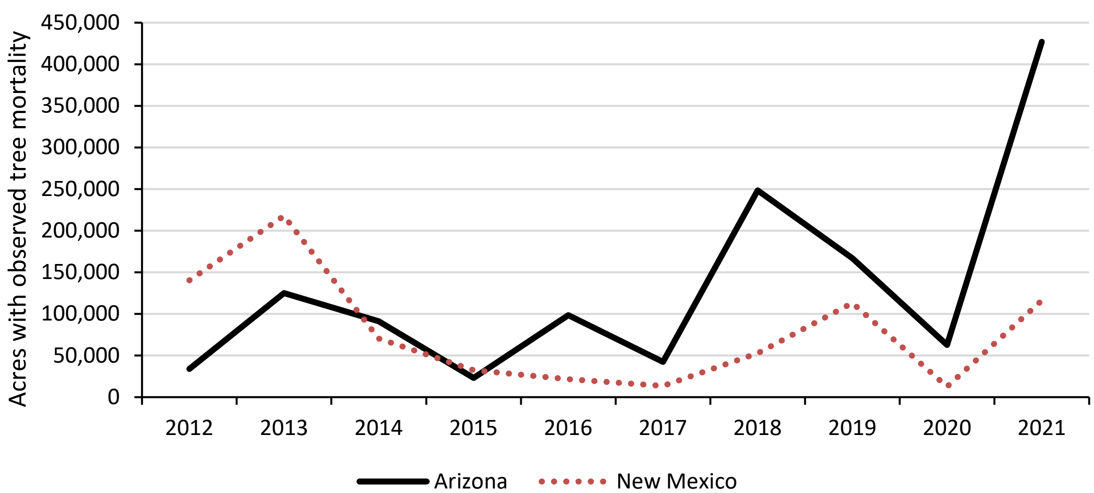

Figure 9. Ponderosa pine mortality attributed to bark beetles in the Southwestern Region for the last ten years.

Figure 10. Ponderosa pine mortality from bark beetles on the Gila NF, New Mexico.

Mixed Conifer Forest Type

Douglas-fir beetle and fir engraver activity in mixed conifer forests increased in 2021 (Figure 11). Most of the mortality (65%) occurred in New Mexico, particularly on the Santa Fe NF. Beetle activity in the mixed conifer forests of the Southwestern Region is commonly associated with stress due to wildfires, severe defoliation events, root diseases, and drought.

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 or drought stress. 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 2021, Douglas-fir mortality from Douglas-fir beetle more than doubled from 14,130 acres mapped in 2020 to 33,360 in 2021 (Figure 11). New Mexico accounted for 85% of the total Douglas-fir beetle activity in the region. Douglas-fir beetle activity increased on all NFs of New Mexico, with most occurring on the Santa Fe NF where 12,730 acres with mortality were mapped in 2021 compared to 7,450 in 2020 (Figure 12). In addition, Navajo Nation and Taos Pueblo Tribal Lands as well as State and Private lands all saw increases in Douglas-fir beetle activity, increasing by 580, 540, and 1,310 acres respectively. All ownerships in Arizona experienced increases in mortality attributed to Douglas-fir beetle, except for the Apache-Sitgreaves NFs which decreased from 130 acres in 2020 to 30 in 2021 and White Mountain Apache Tribal Lands which decreased from 220 acres in 2020 to 160 in 2021 (Table 2). Navajo Nation Tribal Lands in Arizona experienced an increase in Douglas-fir beetle activity, rising from 330 acres with mortality in 2020 to 1,220 in 2021.

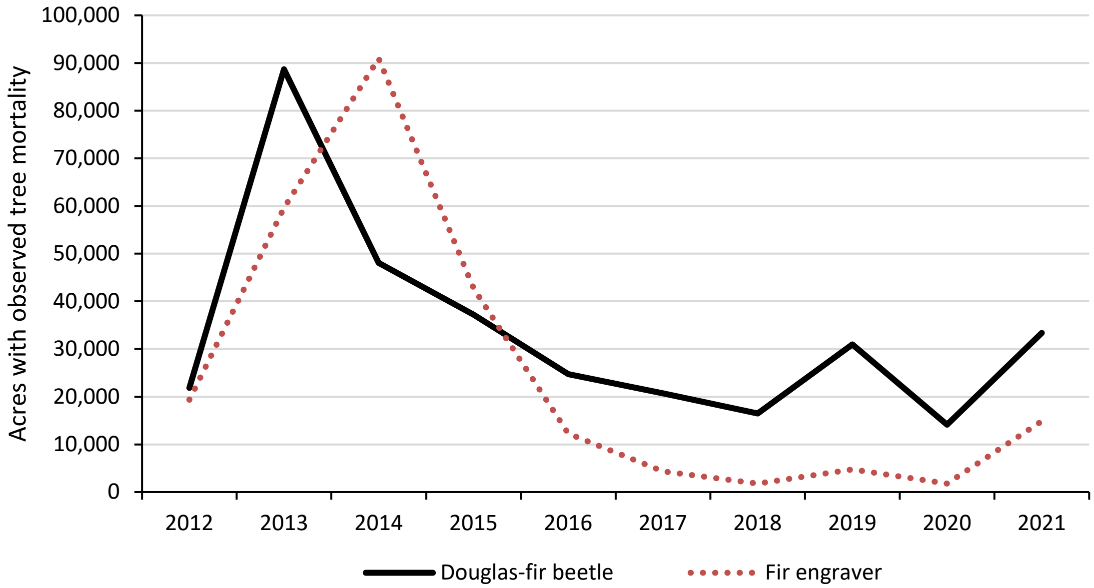

Figure 11. Mixed conifer mortality associated with Douglas-fir beetle and Fir engraver in the Southwestern Region over the last ten years.

Figure 12. Douglas-fir mortality from Douglas-fir beetle in a mixed conifer stand of the Jemez Mountains, Santa Fe NF. Older tree mortality can be seen as dull, purple/gray and current year tree mortality as orange red.

Fir Engraver

Scolytus ventralis
Host: White fir

White fir mortality from fir engraver beetles often occurs when trees are exposed to 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 increased considerably regionwide, with total acres mapped rising from 1,780 in 2020 to 14,880 in 2021 (Figure 11). In Arizona, fir engraver activity increased from 1,090 acres mapped in 2020 to 11,920 in 2021. Most of the mortality in Arizona occurred on White Mountain Apache Tribal Lands (39%) where area affected increased dramatically from 70 acres in 2020 to 4,690 acres in 2021. Activity on the Coconino (24%) and Coronado NFs (10%) increased from 460 acres in 2020 to 2,860 acres in 2021 and 340 acres in 2020 to 1,170 acres in 2021, respectively. In New Mexico, acres with mortality rose from 690 in 2020 to 2,950 in 2021. Most white fir mortality in New Mexico was reported on the Cibola (51%) and Santa Fe (29%) NFs as well as on State and Private lands (11%). Fir engraver activity spiked on the Cibola NF from 2020 levels, increasing from 210 acres to 1,500 acres in 2021. The mortality on the Cibola NF is related to a Douglas-fir tussock moth outbreak that heavily defoliated parts of the Sandia Mountains in the late 2010s.

Ips

Ips bonanseai
Host: Southwestern white pine

Ground surveys from 2018-2021 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 and within the perimeter of the Bighorn Fire in the Santa Catalina Mountains on the Santa Catalina RD, Coronado NF. Mountain pine beetle was also present in some of these dead trees in the Frye Fire. *Ips bonanseai* are not generally considered aggressive tree killers. It is suspected that the beetles were exploiting trees stressed by ongoing drought and the 2017 fire. These areas will continue to be monitored with ground surveys in 2022. More information can be found in the “Other Entomology and Pathology Activities in 2021” section of this document under “Bighorn Fire, Coronado National Forest”.

Spruce-fir Forest Type

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

Spruce Beetle

Dendroctonus rufipennis
Host: Spruce

Regionwide acres with spruce mortality attributed to spruce beetle increased slightly from 33,250 in 2020 to 34,930 in 2021 (Figure 13). In Arizona, spruce beetle activity decreased from 2,240 acres in 2020 to 530 in 2021. Most of the activity occurred on the Kaibab NF (49%) which increased from < 5 acres in 2020 to 260 in 2021. Acres with spruce mortality also increased on the Coconino NF from < 5 acres in 2020 to 100 acres in 2021. Spruce beetle activity decreased considerably on White Mountain Apache Tribal Lands from 1,800 acres in 2020 to 70 in 2021. The Apache-Sitgreaves NFs saw the first decline in four years decreasing from 130 acres in 2020 to 90 in 2021. Although acres with spruce beetle decreased, symptoms of drought including acres with top-kill attributed to spruce ips and widespread discoloration of Engelmann spruce were observed in the White Mountains of eastern Arizona in 2021. Approximately 2,060 acres with spruce crown discoloration were mapped and not generally associated with insect activity at this location.

New Mexico accounted for most spruce beetle-attributed mortality, representing 98% of the total activity regionwide. Within New Mexico, most of the mortality (53%) was mapped on the Santa Fe NF where spruce beetle activity decreased from 20,390 acres in 2020 to 18,140 in 2021 (Figure 14). In contrast, increases were observed on the Carson NF, which nearly doubled from 7,910 acres in 2020 to 14,740 in 2021. State and Private lands in New Mexico experienced a decrease in spruce beetle activity going from 2,130 acres in 2020 to 1,390 in 2021. Stands experiencing several years of spruce beetle activity have recorded > 50% spruce mortality based on aerial estimates, and little new activity was observed in these areas.

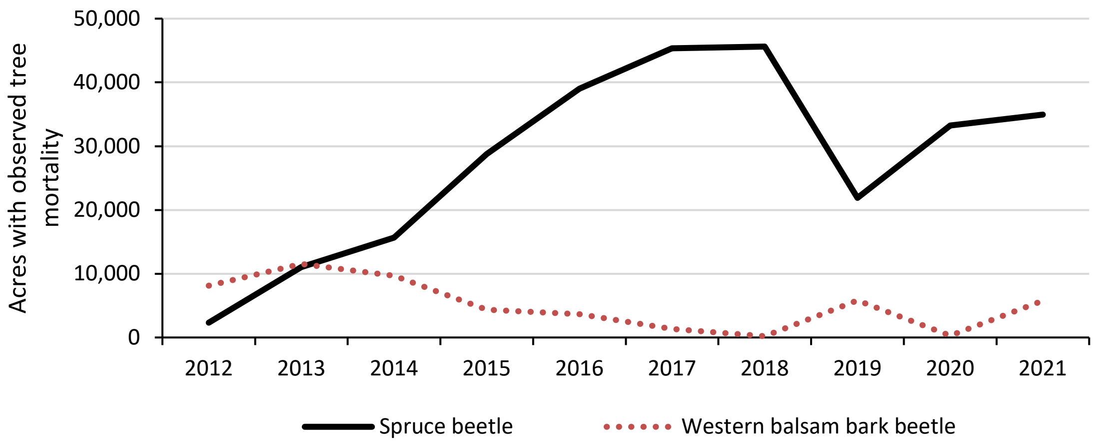

Figure 13. Tree mortality in spruce-fir forests attributed to spruce beetle and western balsam bark beetle in the Southwestern Region in the last ten years.

Figure 14. Spruce beetle activity in the Pecos Wilderness, Santa Fe NF. The ongoing outbreak can be seen through the oldest dead trees (gray), more recent dead (red/purple), and current fading trees which are yellow.

Western Balsam Bark Beetle

Dryocoetes confusus
Hosts: Subalpine and corkbark fir

Figure 15. Western balsam bark beetle in areas affected by root disease near DeMott Park, North Kaibab RD, Kaibab NF.

Fir mortality attributed to western balsam bark beetle (WBBB) increased from 290 acres in 2020 to 5,780 in 2021 (Figure 13). Most of the mortality attributed to WBBB was located in Arizona, which accounted for over 87% of damage recorded regionwide. Within Arizona, mortality was primarily located in Grand Canyon National Park (31%) and on White Mountain Apache Tribal Lands (28%) where WBBB activity increased from 0 acres in 2020 to 1,550 in 2021 and 190 acres to 1,400 acres respectively. Western balsam bark beetle activity also increased on the North Kaibab RD from less than 5 acres reported in 2020 up to 930 acres in 2021. Root disease was also a contributing factor to WBBB activity on the North Kaibab RD, particularly near DeMott Park (Figure 15). Navajo Nation Tribal Lands in Arizona had no observed WBBB activity in 2020, but increased to 660 acres mapped in 2021. Apache-Sitgreaves, Coconino, Coronado, and Kaibab NFs all saw increases in WBBB activity in 2021 as well. In total, less than 30 acres were mapped in these forests in 2020, increasing to 1,410 in 2021 (most notably on the Kaibab NF).

New Mexico also had increased acres affected by WBBB, rising from 80 acres in 2020 to 770 in 2021. Increases in WBBB activity were observed across all ownerships in New Mexico except the Lincoln NF where activity decreased from 30 acres in 2020 to 0 in 2021. The largest increases were observed on Mescalero Apache and Navajo Nation Tribal Lands, going from less than 5 acres in 2020 to 200 acres in 2021 and 0 acres in 2020 to 220 acres in 2021, respectively. Activity on State and Private lands remained low with only 10 acres mapped in 2021. This bark beetle commonly interacts with root diseases caused by *Armillaria* spp. or *Heterobasidion occidentale* to kill trees. The interaction of bark beetles and root disease is common in many forests throughout the West, and signs of infection by *Armillaria* spp. can be consistently found on dead corkbark fir trees in many spruce-fir forests across the region. *Armillaria*-associated mortality is particularly severe and common in the Sandia Mountains of the Cibola NF and Sangre de Cristo Mountains of the Santa Fe NF.

Defoliators

Prominent defoliators discussed in further detail include classic defoliators, like leaf chewing insects, as well as sap sucking insects such as scales and aphids. Damage caused in 2021 ranged from classic defoliation (removal of foliage) to crown discoloration, dieback, and branch flagging. Acres observed with damage from classic defoliators (including less prominent agents not included in Table 3) decreased slightly regionwide from 426,880 in 2020 to 417,070 acres in 2021 (Table 3). Regionally, acres with defoliation attributed to spruce aphid, Janet's looper, and Douglas-fir tussock moth (DFTM) decreased. Both Janet's Looper and DFTM were not observed in 2021, likely ending this latest period of defoliation for these intermittently recurring insects. Aspen damage, including defoliation, dieback, and mortality, decreased on most forests, particularly the Carson NF in New Mexico and the Kaibab NF in Arizona. Observable aspen damage decreased to 20,000 acres in 2021 from 69,120 in 2020 across the region. Needleminer activity doubled from 48,990 acres in 2020 to 100,000 in 2021, entirely in New Mexico on the Carson NF and State and Private lands. Needleminer was primarily observed on the eastern slopes of the Sangre de Cristo Mountains on Vermejo Park Ranch. Pine sawfly, observed at relatively low levels and mostly in localized areas, decreased regionwide. Although western spruce budworm still accounted for the most acres of defoliation in the region, acres mapped decreased from 297,270 in 2020 to 227,740 in 2021. Most of the damage (98%) was in New Mexico, primarily on the Carson and Santa Fe NFs, where the host type is more prevalent.

Pinyon-Juniper Forest Type

Pinyon Needle Scale

Matsucoccus acalyptus
Host: Pinyon pine

After a decrease in 2020, damage attributed to pinyon needle scale increased in 2021, rising from 13,700 acres in 2020 to 53,740 in 2021 regionwide (Table 3). Similar to 2020, most of the damage occurred in Arizona (75%). Large increases were observed on the Prescott NF, Tonto NF, and Hualapai Tribal Lands, which increased from 2,730 acres in 2020 to 9,090 acres in 2021, 2,420 to 9,030, and 1,270 to 7,410, respectively. Substantial damage was also detected in southeastern Arizona on White Mountain (3,450 acres) and San Carlos Apache Tribal Lands (1,060 acres) and on State and Private lands (3,500 acres). Larger pockets of pinyon ips activity were mapped in areas with pinyon needle scale in Arizona in 2021.

New Mexico experienced a dramatic increase in observed defoliation by pinyon needle scale as well, climbing from 840 acres in 2020 to 13,700 acres in 2021 (Figure 16). The largest increase was seen on State and Private lands, which rose from 160 acres in 2020 to 10,585 in 2021 and accounted for 77% of New Mexico's total. Repeated attacks from this insect can cause reduced growth and stunted needles. During severe outbreaks, small trees may be killed directly while larger trees are often predisposed to ips beetles. Depending upon the severity of the defoliation and timing of flights and ground surveys, damage can be quite difficult to observe and, thus, our numbers may vary from year-to-year more than actual incidence on the landscape.

Figure 16. Defoliation of pinyon pine attributed to pinyon needle scale on the Lincoln National Forest.

Ponderosa Pine Forest Type

Pandora Moth

Coloradia pandora
Host: Ponderosa pine

The pandora moth outbreak first reported on the Kaibab Plateau in 2013 has likely ended. 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 was not observed in 2021 with zero acres of damage reported during this feeding year. Damage is not anticipated in 2022.

Pine Sawflies

Neodiprion and *Zadiprion* spp.
Host: Ponderosa pine

Pine sawfly damage decreased across the region, dropping from 1,640 acres in 2020 to 1,060 in 2021. This was driven by a 610 acre decrease on the Coconino NF in Arizona where just 10 acres were mapped in 2021. Although still accounting for the majority of damage in the region, pine sawfly damage remained similar in New Mexico, slightly rising from 1,000 acres in 2020 to 1,050 in 2021. Activity on State and Private lands increased from 770 acres in 2020 to 910 acres in 2021, while activity on the Gila NF decreased from 230 acres in 2020 to 140 acres in 2021. The outbreak near the Luera Mountains and in the Gila NF continued. Ground surveys identified a new area of sawfly activity on the Santa Fe NF after the aerial survey season in the Caja del Rio area, Espanola RD (Figure 17).

Figure 17. Pine sawfly larvae observed feeding in the Espanola RD, Santa Fe NF, New Mexico. Pine sawflies are also exhibiting defensive posture with regurgitate droplets formed at their mouthparts.

Pine Needleminer

Coleotechnites ponderosae
Host: Ponderosa pine

Figure 18. Needleminer larvae in ponderosa pine observed on the Carson NF, New Mexico.

Ponderosa pine defoliation attributed to ponderosa pine needleminers has been mapped in New Mexico for the past four 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 (Figure 18). This defoliation increased to 100,000 acres in 2021, compared to 48,990 acres in 2020. State and Private lands, namely Vermejo Park Ranch, accounted for 88% of the total damage attributed to pine needleminer in 2021, with 88,030 acres mapped. It is not known whether needleminer is solely responsible for the observed damage over the entire Vermejo Park Ranch area, as defoliation from needleminer has only been verified to specific locations. Another area of discolored ponderosa pine mapped on the Carson NF surrounding Tres Piedras was confirmed from ground samples to be needleminer activity. Sporadic needleminer activity was also observed on other parts of the Carson NF near Canjilon but seemed to be a more minor issue compared to widespread drought-induced discoloration in those areas (see Abiotic Damage section). No needleminer activity was observed in Arizona in 2021.

Prescott scale

Matsucoccus vexillorum
Host: Ponderosa pine

Prescott scale is a sapsucking insect that feeds below second year needle bracts at the tips of ponderosa pine tree branches. Young dense stands typically suffer more damage, and damage symptoms have historically coincided with drought conditions and warm dry winters when the trees cannot wall off lesions created by insect feeding as readily. This results in tip flagging in early spring. The most noticeable symptom, branch flagging, was widespread on White Mountain Apache Tribal Lands, especially around McNary and Hawley Lake where 1,300 acres with severe branch flagging were documented during aerial detection surveys (Figure 19). Egg masses were used to validate Prescott scale as the damage causal agent in several locations in 2021. Fifty acres were also detected on neighboring Apache-Sitgreaves NFs.

Figure 19. Widespread branch flagging in young, dense ponderosa pine stands caused by Prescott scale, White Mountain Apache Tribal Lands, eastern Arizona. Flagging is so severe in affected crowns that nearly the entire crown appears brown.

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 69,120 acres in 2020 to 20,290 in 2021. Much of the damage (77%) was observed in New Mexico, particularly on the Santa Fe NF (Table 3). Aspen damage decreased in New Mexico, from 44,010 acres with damage observed in 2020 compared to 15,490 in 2021. The Carson NF experienced the largest decrease in acres affected, decreasing from 21,440 acres in 2020 to 1,730 in 2021. The Santa Fe NF also saw decreased activity, dropping from 14,820 acres in 2020 to 7,230 in 2021. The damage on the Carson and Santa Fe NFs has primarily been defoliation by western tent caterpillar, but large aspen tortrix was also observed affecting areas of high elevation aspen in the Sangre de Cristo Mountains in 2021.

Similarly, acres of aspen damage observed by aerial surveys decreased in Arizona, from 8,310 acres in 2020 to 4,800 acres in 2021 (Table 3). Acres with damage decreased most on the Kaibab NF, from 4,290 acres in 2020 to 1,040 acres in 2021.Western tent caterpillar and large aspen tortrix both contributed to defoliation mapped on the North Kaibab RD and adjacent Grand

Canyon National Park (Figure 20). Damage also decreased on Navajo Nation and White Mountain Apache Tribal lands from 1,760 to 1,400 acres and 750 to 350 acres respectively from 2020 to 2021. Although a decrease in damage was mapped from the air, extensive 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, widespread establishment of an exotic insect, oystershell scale, has been placing further stress on aspen in Arizona, particularly on smaller size classes that are often lacking on the landscape due to chronic browse by ungulates. More information on aspen monitoring in Arizona may be found in the “Other Entomology and Pathology Activities in 2021” section of this document under “Aspen Monitoring in Northern Arizona”.

Figure 20. Aspen defoliation from western tent caterpillar and large aspen tortrix on the North Kaibab Ranger District, adjacent to Grand Canyon National Park.

Douglas-fir Tussock Moth

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

Douglas-fir tussock moth (DFTM) activity was not detected in Arizona or New Mexico in 2021. Only 200 acres were mapped in 2020, most of which were observed in Arizona on the Coconino and Tonto NFs. Trapping results from 2021 indicate increasing populations in the Pinal Mountain Recreation area on the Tonto NF and on Mount Graham near Safford, Arizona on the Coronado NF. Populations have increased above the trapping threshold of 25 male moths on average per site at each location. Visible defoliation may occur in these areas during the next few years if the population is not controlled by natural factors.

Western Spruce Budworm

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

Western spruce budworm (WSBW) activity decreased across the region from 297,270 acres in 2020 to 227,740 acres in 2021, reversing an upward trend in damage attributed to this insect since 2018 (Figure 21). Most of the damage and reduced acreage in the Southwestern Region occurred in New Mexico, which accounted for over 98% of the total damage by WSBW. Most of the mapped defoliation occurred on State and Private lands, followed by the Carson and Santa Fe NF, which accounted for 36%, 32%, and 19% of statewide damage, respectively. Mapped damage on the Carson NF decreased by 42,220 acres, Santa Fe NF declined by 34,100 acres, and State and Private lands dropped by 4,380 acres in 2021. State and Private lands had the most acres with damage in New Mexico, with 80,280 acres observed in 2021. In contrast, increased activity was observed on Lincoln NF as well as Jicarilla Apache, Navajo Nation, and Taos Pueblo Tribal Lands in 2021. Lincoln NF activity grew from 2,360 acres affected in 2020 to 6,530 in 2021. Jicarilla Apache Tribal Lands increased from 5,640 acres in 2020 to 6,780 acres in 2021. Similarly, Navajo Nation and Taos Pueblo Tribal Lands rose from zero acres in 2020 to 2,580 acres in 2021, and 3,120 to 5,640, respectively. Elevated levels of defoliation have been observed for at least four decades in both dry and wet mixed conifer stands, as well as some spruce-fir stands of the region. Douglas-fir, white fir, and Engelmann spruce have all been surveyed 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 Arizona, acres affected by WSBW increased from just 530 acres in 2020 to 4,530 in 2021. Most of the damage was observed on White Mountain Apache and Navajo Nation Tribal Lands, both increasing from zero acres in 2020 to 1,710 and 980 acres in 2021, respectively. Although aerial surveys identified large amounts of suspected WSBW activity on White Mountain Apache Tribal Lands (Table 3), we did not see evidence of WSBW during ground monitoring in those same locations, and the mapped crown discoloration may be the result of drought conditions. Apache-Sitgreaves, Coconino, and Kaibab NFs also saw increases in activity growing by 680, 310, and 230 acres, respectively. Defoliation by WSBW was confirmed on the San Francisco Peaks, Coconino NF and on the North Kaibab RD, Kaibab NF. The amount of observed WSBW damage fluctuates from year to year with weather and environmental conditions.

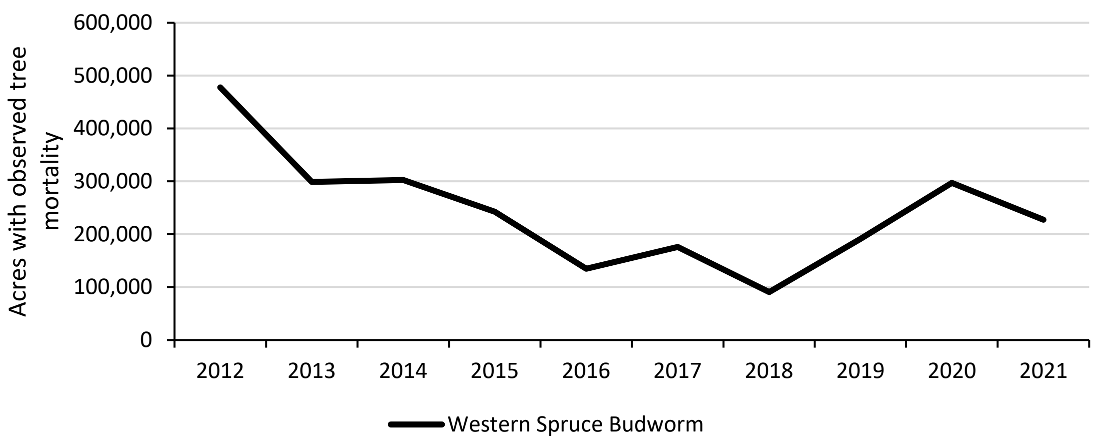

Figure 21. Defoliation attributed to western spruce budworm in the Southwestern Region for the last ten years.

Janet's Looper

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

In New Mexico, uncharacteristic mixed conifer defoliation was observed near Tesuque Creek 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 as a winter feeder. As a result, special flights were conducted in May of 2018 and 2020 to map the area affected and avoid confusion with defoliation caused by western spruce budworm. Activity from Janet's looper continued to subside in 2020 and therefore no special flights occurred in 2021. No damage attributed to Janet's looper was detected in New Mexico for 2021, likely indicating an end to the outbreak. Janet's looper outbreaks can develop rapidly, last two to three years, and collapse due to starvation, parasites, and disease.

Spruce-fir Forest Type

Spruce Aphid

Elatobium abietinum
Hosts: Engelmann and blue spruce

Spruce aphid is an exotic invasive insect that can cause significant damage and mortality of Engelmann spruce (Figure 22). Most of the damage regionwide typically occurs in Arizona with periodic outbreaks in the White Mountains and Pinaleño Mountains of eastern Arizona. Acres with defoliation from this insect decreased for a third consecutive year in 2021 after spiking in 2016 and 2018 (Figure 23). In 2021, 310 acres with defoliation attributed to spruce aphid were mapped compared to 2,230 acres in 2020. All the damage was 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). Acres with defoliation decreased most substantially on White Mountain Apache Tribal Lands from 1,430 acres in 2020 to 130 in 2021. 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 10 acres reported in 2020 to 50 acres in 2021.

No spruce aphid activity was observed in New Mexico in 2021. The most recent spruce aphid activity observed in New Mexico was reported at Ski Apache on the Lincoln NF during the winter of 2018-2019. At that time, ground visits identified feeding damage and some live aphids; no damage has been reported in New Mexico recently.

Figure 22. Cumulative mortality across high elevation spruce fir forest on White Mountain Apache Tribal Lands, resulting from several consecutive years of spruce aphid outbreaks.

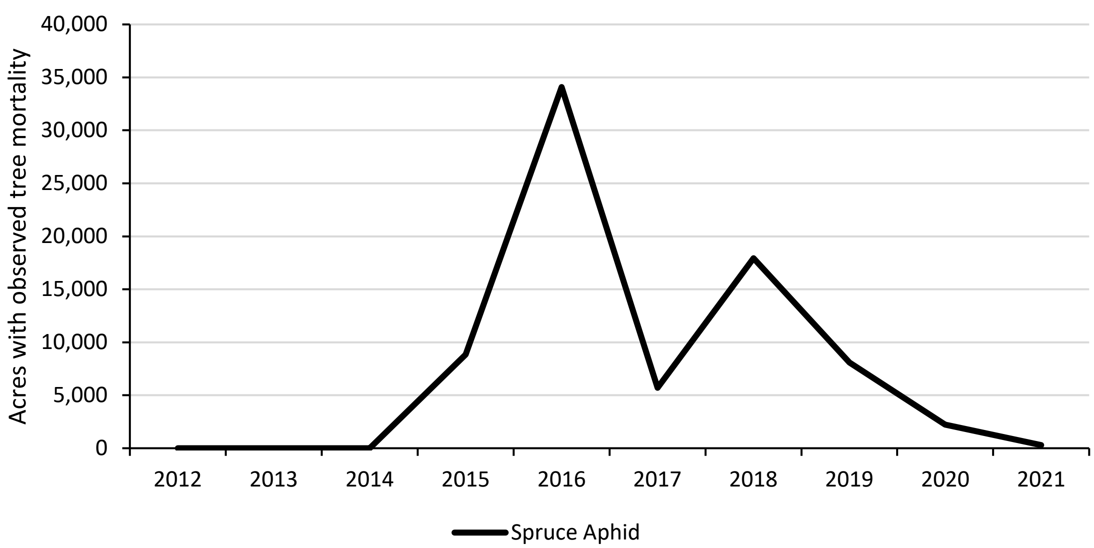

Figure 23. Defoliation attributed to spruce aphid in the Southwestern Region over the last ten years.

Miscellaneous Insects

Defoliators

Box elder tussock moth

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

Orgyia lueschneri is a pale-yellow tussock moth that can be observed feeding on riparian hosts, predominantly in canyons of the southwestern and western United States (Figure 24). Outbreaks periodically occur in Arizona where this insect is commonly observed feeding on box elder along Oak Creek Canyon. In 2021, *O. lueshneri* was still active around the Oak Creek Canyon Visitor Center near Indian Gardens and in Red Rock State Park.

Figure 24. *Orgyia lueschneri* larvae on its preferred host, box elder, in Oak Creek Canyon, Coconino National Forest.

Mourning Cloak

Nymphalis antiopa L.
Hosts: Willow, elm, aspen, poplar, cottonwood, birch, hackberry, hawthorn, rose, and mulberry

A small group of mourning cloak caterpillars were observed during a ground check of aerial survey damage on aspen in the Carson NF, east of Taos (Figure 25). Aspen in the area were also being defoliated by large aspen tortrix and western tent caterpillar. Mourning cloak in not a serious pest and causes minor defoliation. Young caterpillars feed gregariously and are early season defoliators. Mourning cloaks have one to two generations per year, and adults are relatively long-lived (> 10 months).

Figure 25. Mourning cloak caterpillar feeding on aspen in the Carson NF, New Mexico.

Aphids

Aphididae
Hosts: Pines (*Cenaria* spp.) and hardwoods

Due to the extended warm fall weather, significant populations of aphids were observed across several locations in Yavapai County in late November. Populations increased on pines and scrub oaks throughout urban and forested areas surrounding Prescott, Arizona.

Status of Major Diseases

Mistletoes

Dwarf Mistletoes

Arceuthobium spp.
Hosts: Conifers

Figure 26. 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 26) 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 such as bark beetles. Dwarf mistletoes have an ecological role, as they provide bird roosting habitat and an occasional food source for some mammals and birds. There are eight species of dwarf mistletoe in the region, each with a primary tree host. The species that primarily affect ponderosa pine, pinyon pine, and Douglas-fir are the most common and are found throughout most of their respective host ranges, while the other species have more limited distributions (Figure 27). In 2021, measurements continued on a permanent plot network established in 1991. These data will provide information on dwarf mistletoe incidence, impacts, and rate of spread. More information can be found in the "Other Entomology and Pathology Activities in 2021".

True Mistletoes

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

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

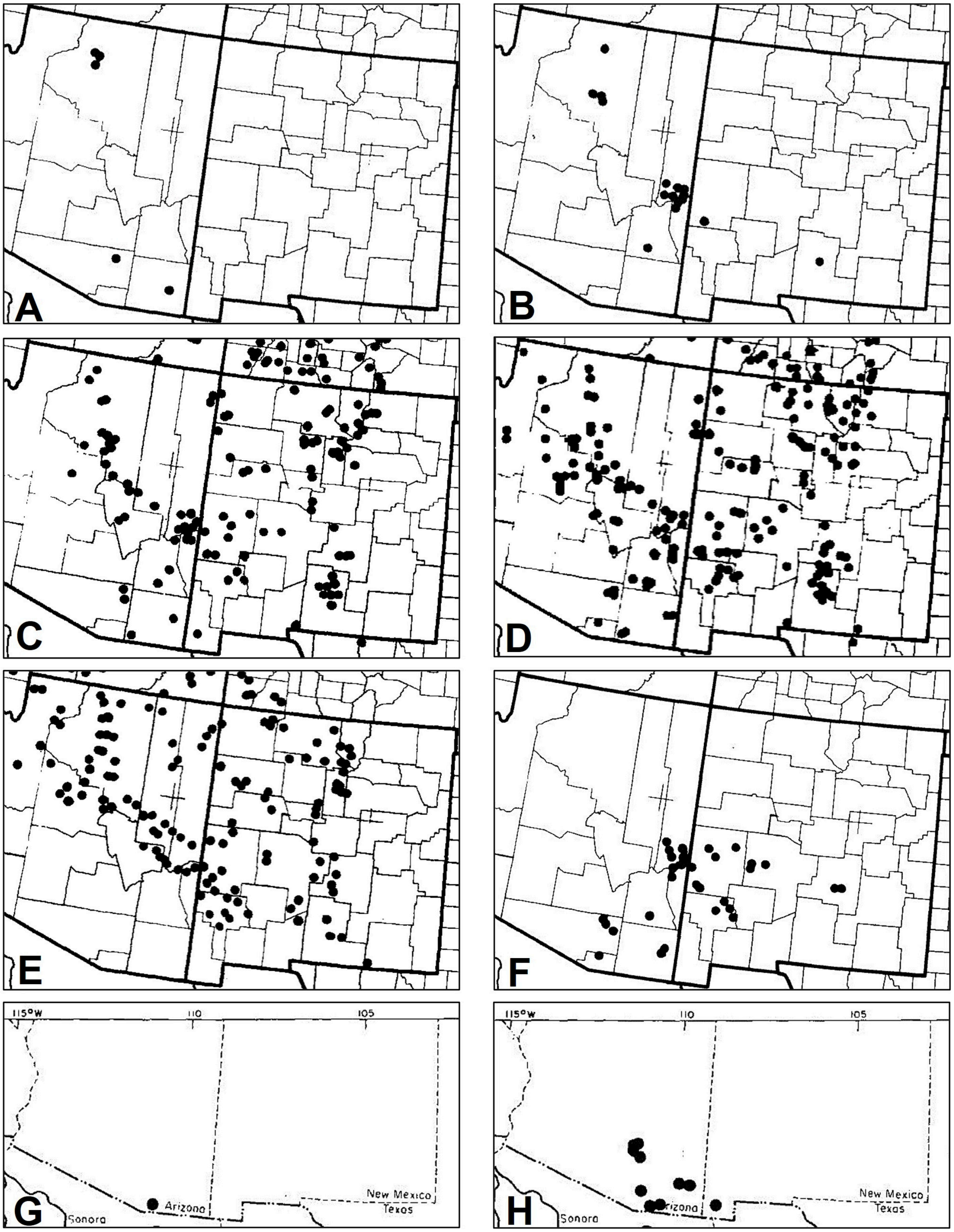

Figure 27. Distributions of dwarf mistletoe species in the Southwestern Region principally infecting white fir (A, *Arceuthobium abietinum* f. sp. *concoloris*), spruce (B, *A. macrocarpum*), Douglas-fir (C, *A. douglasii*), ponderosa pine (D, *A. vaginatum* subsp. *cryptopodum*), pinyon pine (E, *A.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

Root Diseases

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

Armillaria Root Disease

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

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

Figure 28. Mycelial fan associated with Armillaria root rot on a killed Engelmann spruce.

Heterobasidion Root Disease (Formerly Annosus Root Disease)

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

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

Other Common Root Diseases

Figure 29. *Ganoderma applanatum* fruiting body growing at the base of an aspen.

Other common root diseases in the Southwest include Schweinitzii root and butt rot, caused by the fungus *Phaeolus schweinitzii*, which is often found on older Douglas-fir and occasionally on ponderosa pine, southwestern white pine, white fir, and spruce. 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 29). The disease causes crown dieback, windthrow, and mortality, especially in older aspen stands; however, aspen of all ages are affected. Aspen stands on mesic sites seem to have higher incidence of disease compared to drier sites.

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 causing brown rot in the Southwest is red belt fungus, *Fomitopsis schrenkii,* which affects conifers and sometimes aspen. Prominent stem decays causing white rots in the region include red rot, *Dichomitus squalens*, of ponderosa and pinyon pines; red ring rot, *Porodaedalea pini,* affecting most conifers (Figure 30); Indian paint fungus, *Echinodontium tinctorium*, on true fir and occasionally Douglas-fir or spruce; false tinder conk, *Phellinus tremulae*, on aspen; pouch fungus, *Cryptoporus volvatus*, a sap rot found on bark beetle-killed conifers; and *Phellinus everhartii* and *Inonotus dryophilus* on oak species.

Figure 30. Fruiting bodies (conks) of the stem decay red ring rot, *Porodaedalea pini*, on an Engelmann spruce.

Stem Rusts

White Pine Blister Rust

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

White pine blister rust (WPBR), caused by *Cronartium ribicola*, is the only known exotic invasive forest disease in the region (Figure 31). 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.

Figure 31. Aecia growing on a white pine blister rust canker on a southwestern white pine branch.

In New Mexico, this disease continues to cause heavy damage to southwestern white pines on the Sacramento Mountains of southern New Mexico, where the disease has likely been established for over 40 years (Figure 32). Based on a set of representative monitoring plots, roughly 45% of the white pines in this area, which includes Mescalero Apache Tribal Lands and most of the Lincoln NF, are infected. White pine blister rust also occurs on the Gila, Cibola, and Santa Fe NFs of New Mexico.

In 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 32). Age estimation of older cankers suggest the WPBR pathogen may have been present for 20 years but at undetectable levels. Since 2009, favorable weather conditions for the pathogen have allowed for continued disease expansion into new areas, including into more moderate hazard sites throughout most of the White Mountains. However, there are many areas where disease is still absent.

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 2021” section of this document under “White Pine Blister Rust Genetic Resistance”.

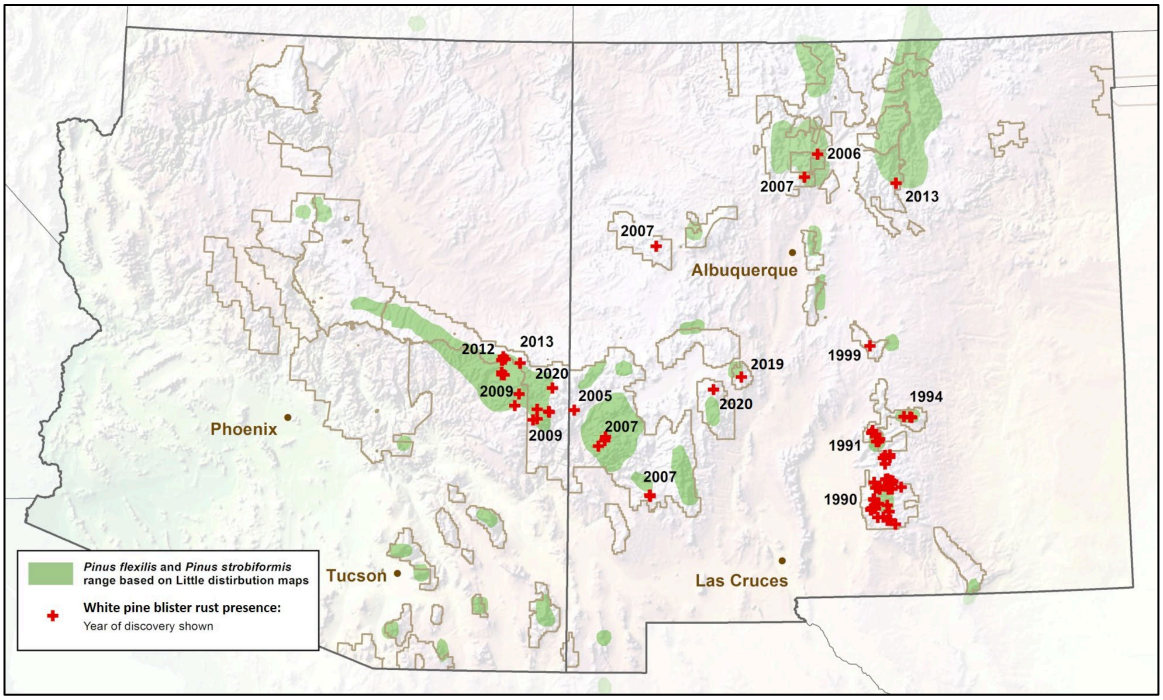

Figure 32. Distribution of known white pine blister rust infection centers within the Southwestern Region and the year in which they were discovered.

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 the Southwest (Figure 33). However, higher infestations of fir broom rust occur on the Sandia and Manzano Mountains of central New Mexico and a few other locations. Damage from this easily recognized disease has not been well quantified, but infection can result in top-kill, especially in spruce. Falling brooms or stem breakage present a hazard in developed recreation sites.

Figure 33. Witches' broom associated with fir broom rust on a 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 infection are initiated by climate conditions conducive to this disease and may occur at intervals of several years.

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

Canker Fungi

Canker diseases are commonly associated with damaged or stressed trees. Disturbances which may inflict mechanical damage to trees or stressors such as drought can increase the incidence of canker diseases. These pathogens are often involved in aspen mortality and dieback due to the soft living tissue of the bark, which makes aspen extremely susceptible to wounding and subsequent infection. Sooty bark canker, caused by *Encoelia pruinosa,* is the most lethal canker of aspen, while Cytospora canker, caused by *Cytospora* spp, is the most common. *Valsa melanodiscus* (anamorph *Cytospora umbrina*) or alder heat canker, continued to be observed in association with dieback and mortality of Arizona alder (*Alnus oblongifolia*) in Oak Creek Canyon in 2021. Alder heat canker has also been associated with large scale dieback and mortality of alder in Alaska, Colorado, and New Mexico.

In 2021, pathogens in the genus *Biscogniauxia* were observed causing dieback and mortality of Emory and silverleaf oaks in many new locations in Arizona, primarily on the Nogales, Douglas, and Safford RDs, Coronado NF and the Pleasant Valley RD, Tonto NF (Figure 34). Dieback and mortality associated with these pathogens was particularly severe in Madera Canyon in the Santa Rita Mountains and along Turkey Creek in the Chiricahua Mountains of Southeastern Arizona. Mortality is distributed across size classes, including sapling sized trees. Prior to 2018, there had been no reports of *Biscogniauxia* spp. affecting oaks in Arizona. Two species have been identified, *Biscogniauxia mediterranea* and a previously undescribed *Biscogniauxia* species. A first report formally documenting *Biscogniauxia mediterranea* causing disease on Emory oak was published in 2021 (Wright et al. 2021). Pathogens of this genus are generally associated with dieback and mortality of drought-stressed trees. As conditions in the Southwest continue to become hotter and drier, it is likely these pathogens will continue to become more prevalent on the landscape.

Figure 34. Fruiting bodies of *Biscogniauxia* spp. emerging from beneath the bark (left image); recent silver leaf oak mortality observed in Madera Canyon (center image, note the light grey fruiting bodies of *Biscogniauxia* spp. covering the bole); and recent mortality of Emory oak saplings near Turkey Creek, Chiricahua mountains (right image).

Foliar Diseases

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

In New Mexico, a small red band needle blight (*Dothistroma septosporum*) infection center was found in 2021 affecting ponderosa pine near Timberon on the Lincoln NF. The fungal disease was observed during aerial detection surveys, and the pathogen was subsequently confirmed morphologically from collected needle samples. The extent of the infection center is unknown as it is somewhat obscured by widespread drought discoloration in the same area.

In Arizona, chronic white pine needle cast caused by *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 35).

Figure 35. Sycamore anthracnose affecting sycamores in Wet Beaver Creek. Note the white defoliated crowns among green crowns of other riparian species.

Abiotic Damage

Salt

De-icing salt use has contributed to continued ponderosa pine damage along highways in the Southwestern Region (Table 4). Approximately 520 acres with salt damage were reported in 2021, increasing from 130 acres in 2020. About 280 acres with damage were mapped in Arizona and 250 acres were mapped in New Mexico. Damage has typically been observed along major corridors, including county and city roadways, as municipalities continue use of de-icing salts. Application of dust abatement salt is also associated with damage to ponderosa pine along dirt roads in rural housing areas.

Red Belt Winter Injury

Late season winter injury can inflict significant damage to affected trees. In New Mexico, a fairly large red belt event was recorded in 2021, with 6,840 acres of damage mapped (Table 4). The discoloration was found on a variety of conifer species of different age and size, including ponderosa pine, Douglas-fir, and white fir. About 85% of this damage occurred on the Lincoln NF (Figure 36), 12% on Mescalero Apache Tribal Lands, and the remaining 3% on State and Private lands. The red belt event was visibly apparent from south of Sierra Blanca north throughout the Smokey Bear RD and included a large area of the Capitan Mountains. Red belt occurs with the sudden appearance of warm dry winds (e.g. Chinook winds) that produce a temperature inversion. A relatively thin layer of warm air arrives that cannot mix downward and continues to contact side slopes. Trees exposed to unseasonably warm air by day receive seasonably cold air at night. This alteration of warm and cold air exposure, along with the frozen condition of the soil, results in desiccation injury because daytime transpiration removes moisture from the needles more rapidly than roots in frozen soil can replace it. Ground surveys will be conducted in 2022 to further assess forest health in impacted areas, though most affected trees are expected to recover.

Figure 36. Red belt discoloration along the crest of a ridgeline northeast of Carrizo Peak (Smokey Bear Ranger District, Lincoln National Forest).

Drought

The Southwestern Region experienced exceptional drought conditions entering 2021. Evidence of this acute stress was observed to some extent in all tree species but was particularly severe in pinyon-juniper woodlands and ponderosa pine (Table 4). Large areas of crown dieback of junipers across Arizona and in southeast New Mexico were mapped in 2021. In Arizona, drought related crown dieback of juniper was observed on 334,100 acres across multiple ownerships. In New Mexico, 23,720 acres of juniper dieback was mapped, most of the damage located around the Guadalupe Mountains, Lincoln NF (90%).

Drought stressed ponderosa pine exhibited slight yellowing of needles and some premature needle loss. Symptoms were most evident on dry ridges and upper slopes (Figure 37). New Mexico accounted for most of the drought stress mapped in ponderosa pine with 121,360 acres in 2021, compared to 36,010 acres in 2020 (Table 4). Most of this was mapped on State and Private lands (45,920 acres) and the Carson NF (26,080 acres). In Arizona, 18,720 acres of ponderosa drought impacts were mapped with most of the observed drought activity on the Apache-Sitgreaves NFs (11,980 acres). In 2020, only 940 acres of ponderosa pine drought stress were mapped in Arizona. In addition, drought stress affecting other species rose from just over 14,000 acres in 2020 to 48,950 acres in 2021. Most of this damage was mapped on the Coconino (11,640 acres), Kaibab (8,230 acres), and Coronado NFs (6,420 acres). Widespread drought-driven defoliation was observed in many deciduous oak species throughout Arizona and New Mexico in the spring / early summer. Stress may increase susceptibility to drought driven pathogens and pests such as *Biscogniauxia* spp. and goldspotted oak borer. After precipitation occurred with the summer monsoon season, most of these oak woodlands were able to re-flush (Figure 38). Delayed, late season mortality associated with drought stress can be high, and normal ADS flights may underestimate mortality in years of acute drought. Drought stress may increase susceptibility to insects and diseases which do not affect vigorous trees. Drought may also act as a principal mortality agent in some cases.

Figure 37. Drought stress observed on ponderosa pine discolored yellowish-brown on the San Mateo Mountains, Cibola National Forest.

Figure 38. Oak stand located in the Santa Rita Mountains exhibiting drought-related defoliation (left image, note the brown discoloration and defoliation; the only green crowns are conifers) and the same oak stand following the onset of monsoonal moisture (right image, note the lush green color of new foliage compared to before the monsoon).

Hail Damage

Defoliation attributed to hail damage increased regionwide, rising from 30 acres in 2020 to 3,400 in 2021 (Table 4). All the damage occurred on the Santa Fe NF and was observed during special survey flights for pinyon mortality in the area. A large swath of gray ponderosa pine along the western edge of the Santa Fe NF was observed on Cuba Mesa (Figure 39). Ground checks later revealed numerous broken branches scattered across the forest floor and thin tree crowns over nearly the entire mesa, indicative of a hail event. Hail impacts the tree by breaking fine branches and foliage, often resulting in a thin appearance and a gray aerial signature.

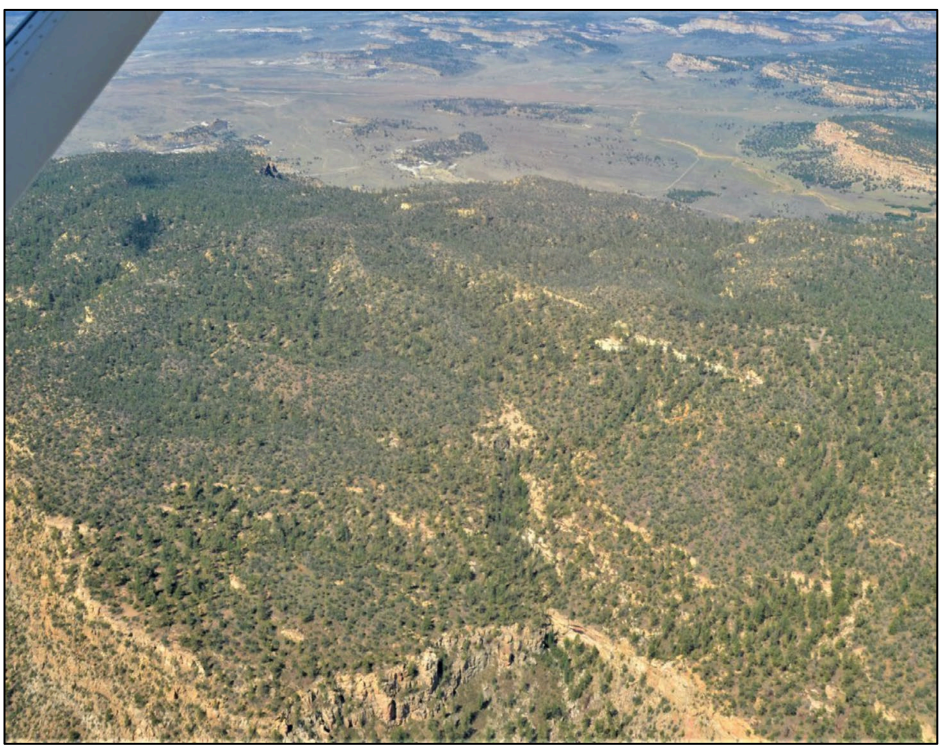

Figure 39. Hail damage of ponderosa pine (gray discoloration) on Cuba Mesa, Santa Fe National Forest.

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

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

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

Figure 40. 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 41). This bunchgrass species was originally imported from Eurasia and northern Africa in the early 1900s for erosion control and as a forage crop for haying and grazing. Yellow bluestem is very adaptable and highly aggressive, especially in disturbed areas. It can form a monoculture that lowers biodiversity of native plant communities by reducing abundance, diversity, and richness of native plant species. Infestations of yellow bluestem also alter soil carbon: nitrogen ratios and the composition of soil microbial communities, including arbuscular mycorrhizae. This transformation in soil properties can inhibit growth of native plant species. In addition, yellow bluestem-infested areas can be relatively unsuitable for nesting, brood rearing, or year-round habitat for grassland bird species. The lower bird numbers may reflect decline in arthropod abundance and/or biomass.

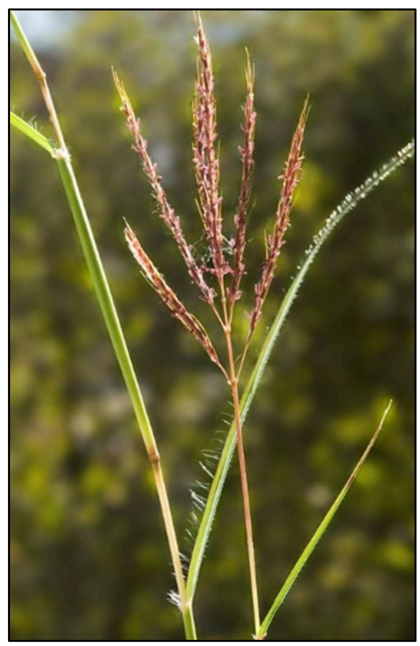

Figure 41. Yellow bluestem panicle (courtesy photo by Billy Warrick; Soil, Crop and More Information).

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 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 42). 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 42. 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.).

In 2021, aerial surveys detected tamarisk leaf beetle caused defoliation on 7,110 acres in Arizona with new impacts detected further south along the Salt and Black Rivers on Apache Tribal Lands and Tonto NF near Lake Roosevelt. Eighty-eight percent of the damage was detected on tribal lands, nearly 10 percent was observed on State and Private lands, and the remaining damage occurred on the Tonto NF.

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, toadflax, 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 (wsommers@dffm.az.gov) 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 2021

Forest Health Regional Training

The FHP staff provides annual training opportunities to resource managers on insect and disease identification, effects, and management as well as hazard tree identification and mitigation. In 2021, due to the COVID-19 pandemic, these trainings were held virtually. Presentations were given live via Microsoft Teams, and attendance was at an all-time high and included multiple agencies and diverse stakeholders. Presentations were also recorded and made available to internal and external partners. Although the post-training assessment response was quite positive, attendees did prefer to have a field component included. Typically, this regional training occurs annually with the location alternating between Arizona and New Mexico. Another virtual regional training is being planned for 2022, followed by field days in each respective FHP zone.

Dwarf Mistletoe Plot Re-Measure

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

White Pine Blister Rust Genetic Resistance

In 2021, FHP continued work to sustain southwestern white pine and limber pine in the face of the introduced pathogen *Cronartium ribicola*, the causal agent of white pine blister rust. This work is being conducted in collaboration with Dr. Kristen Waring of Northern Arizona University, Dr. Owen Burney of New Mexico State University, Dr. Richard Sniezko of the Dorena Genetic Resource Center (DGRC), and others. We have collected seed from trees (parent trees) across the range of SWWP to grow and test for resistance to WPBR and assess adaptive traits (Figure 43). Progeny of these parent trees were inoculated with *Cronartium ribicola* at DGRC in Cottage Grove, OR to evaluate resistance. A small percentage (around 5%) of trees have shown resistance in these trials with locations of parent trees distributed across much of the Region. Two field trials have been established in cooperation with the Mescalero Apache Tribe (2017) in New Mexico and the Apache-Sitgreaves National Forests (2018) in Arizona. These are long-term, fenced test sites that will be used to evaluate the durability of

Figure 43. Mescalero Apache personnel planting the field site located on Mescalero Apache Tribal Lands in 2021.

various disease resistance mechanisms observed at DRGC. In 2021, 1,200 trees were planted in the Arizona field site, bringing the total number of trees planted there to 2,292. Planting in the Arizona site was completed by the Arizona Conservation Experience (ACE), a contract which yielded an opportunity for outreach and education with the field planting crew. At the field site in New Mexico, 1,160 trees were planted in 2021, bringing the total number of trees planted there to 1,391. Planting was completed by Mescalero Apache personnel (Figure 43). A total of 2,360 trees were planted between the two sites in 2021. Additional plantings to replace killed seedlings and increase diversity of genotypes being tested on the site will occur in future years. In addition, FHP has collected scion from parent trees throughout the region over the last several years which have shown some level of resistance to white pine blister rust, either via major gene resistance or quantitative resistance. No scion was collected in 2021. Overall, resistant trees have been collected from the Lincoln NF and Mescalero Apache Tribal Lands in southern New Mexico, the Zuni Mountains (Cibola NF) of northern New Mexico, and the White Mountains of Arizona (Apache-Sitgreaves NFs). Scion material is being grafted into a seed orchard in Mora, NM and will also be used to provide disease resistant seed for future reforestation efforts. *For more information, contact Gregory Reynolds or Nicholas Wilhelmi.*

Fungal Diversity in Conifer Nurseries throughout the Region

Plant pathologists Greg Reynolds and Nicholas Wilhelmi (New Mexico and Arizona Zones, respectively) are collaborating with researchers John Dobbs and Jane Stewart from 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 west (Figure 44). These pathogens can cause seeding 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 continued in 2021, with a tribal facility and two state university facilities assessed. Thus far, we have isolated and identified *Fusarium oxysporum, F. commune, F. proliferatum, F. solani, F. avenaceum, F. acuminatum,* and *F. lactis* from diseased conifer seedlings growing in nurseries of the Southwestern Region. *For more information, contact Gregory Reynolds or Nicholas Wilhelmi.*

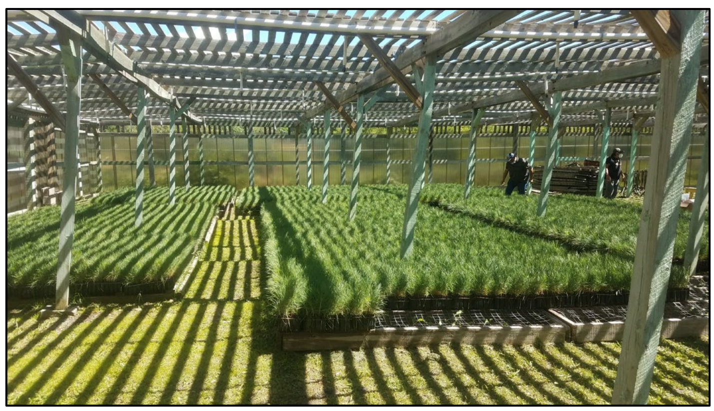

Figure 44. Ponderosa pine production at a nursery sampled for fungal pathogens in the Southwestern Region.

Aspen and Oystershell Scale 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 2021, FHP continued collaboration with Dr. Kristen Waring and Connor Crouch (Ph.D. student) of Northern Arizona University 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 a 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 2021, plot networks were expanded on the Coconino, Kaibab, and Apache-Sitgreaves NFs. Plots installed on the Black Mesa RD, Apache-Sitgreaves NF and Mogollon Rim RD, Coconino NF were placed in ungulate exclosures infested with OSS (Figure 45). These exclosures will be treated to assess the efficacy of various silvicultural treatments on mitigating OSS and to monitor the impacts of prescribed fire on OSS. Plots will be reassessed following treatments. Currently there is no published information on the efficacy of silvicultural treatments related to OSS management. *For more information, contact Amanda Grady.*

Figure 45. Aspen stem infested with oystershell scale. Note the orange *Cytospora* spp. spore tendrils emerging.

Bighorn Fire, Coronado National Forest

The Bighorn Fire was started by lightning on June 5th, 2020 and burned close to 120,000 acres on the Santa Catalina Mountains in southeastern Arizona just outside of Tucson. This sky island provides crucial habitat for the endangered Mexican spotted owl (MSO). Douglas-fir is a central tree species in foraging and roosting areas for these birds. Concerns about the potential for a Douglas-fir beetle (DFB) outbreak prompted the Coronado NF to acquire funding from the Burned Area Emergency Response (BAER) post-fire for a project designed to protect Douglas-fir trees in crucial areas of the remaining MSO habitat. This project used the anti-aggregation pheromone, 3-methylcyclohex-2-en-1-one (MCH), to deter beetle attacks on Douglas-fir trees. Pheromones were deployed as area protection, in a grid pattern, across ≈520 acres of critical owl habitat. We also deployed Lindgren funnel traps baited with aggregation pheromones for two beetle species of interest, DFB and mountain pine beetle (MPB), to monitor relative population size and flight seasonality. Although the Santa Catalinas have not had a history of MPB outbreaks, this species has caused mortality in southwestern white pine trees after several recent fires in Arizona (Wallow Fire, Schultz Fire, and Frye Fire; USFS, Aerial Flight Detection Surveys) and thus monitoring seemed prudent. In addition, ground surveys were conducted to assess tree mortality and beetle attacks and assess the effectiveness of the pheromone treatments.

To briefly summarize; for 2021, beetle catches and ground surveys indicate that beetle activity is very low. Douglas-fir beetle trap catches (<1 beetle/trap/day) peaked in June. No MPB were collected in our traps. During our surveys we found 2% of the Douglas-fir trees and 14% of the southwestern white pines (SWWP) had evidence of beetle activity. The majority of the attacks were strip attacks. In addition, for the SWWP, we saw no attacks from MPB. Instead, attacks were from a secondary beetle, *Ips bonanseai*, known to respond to stressed trees. Unfortunately, no anti-aggregation pheromones are known for this species. Based on the low trap catches and the lack of active attacks from beetles for which pheromone treatments exist, we do not recommend pheromone treatments in 2022. This is also due to the difficult terrain encountered during deployment of the pheromones. We would advise continued monitoring in 2022.

History Grove Douglas-Fir Beetle Push-Pull Strategy

In FY 2021, data collection on tree mortality was finalized within an old growth stand called the History Grove on the Valles Caldera National Preserve, New Mexico. In 2013, the Thompson Ridge Fire burned nearly 100 km^2 of forested area in and around the Valles Caldera National Preserve. The fire damage and impending Douglas-fir beetle (DFB) attacks could potentially be a serious threat to the 125-acre old-growth stand. The History Grove consists of 250–400-year-old ponderosa pine and Douglas fir trees that pre-date 20th century logging (Figure 46). Douglas-fir mortality increases after fire as scorched trees that would have otherwise survived the fire later succumb to DFB. Preventative management practices of sanitation and salvage may reduce DFB outbreaks post-fire. However, site sensitivity, access, and remote location often limit these approaches, and semiochemical tactics are used as an alternative for protective management of high value stands.

Figure 46. History Grove, Valles Caldera National Preserve, New Mexico. Photo taken from NPS courtesy of Seth Gayner.

The objective of this long-term study in conjunction with the National Park Service is to determine if a push-pull strategy using aggregation pheromones on already killed or attacked trees and anti-aggregation pheromones on unscorched and un-attacked mature old-growth Douglas-fir could limit losses by DFB within the History Grove post fire. In addition, pheromone trapping using Lindgren traps was deployed to elicit phenology and ecology of DFB flight, abundance, and potential responding natural enemies and non-targets. Surviving Douglas-fir trees were assessed in 2021 with identification of all insects captured in the traps. Data analysis and manuscript may be completed by the end of 2022. *For more information, contact Steve Souder.*

Twig Beetle Special Project

We have (1) carried out high intensity collections of multiple species of walnut trees and populations and lineages of walnut twig beetle (WTB) and *Geosmithia morbida* in the Southwest; (2) evaluated these native and ancestral populations to finely map the host and pest organism distributions; and (3) used statistical techniques to determine degree of genetic exchange between invasive and non-invasive forms of the pests that may have facilitated aggressiveness and spread of thousand cankers disease (TCD) in USA and Europe. The data from the first three objectives are being synthesized into an updated and higher accuracy host layer to improve the Risk Map and FHTET 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 2022, we are working 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 (CA alone for *G. morbida* and WTB), and subset of CA samples in relationship to other western USA locations. In addition, across all years where samples were collected, we had 43 instances in which WTB were paired with *G. morbida* isolates from the same location-host combination. That part of the project and data analyses related to co-evolution of the two will be completed in FY 2022 (collaboration with UTK computer scientists). Our group expects this publication to be drafted in 2022. *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.*

Juniper Dieback and Mortality Monitoring

Extreme and exceptional drought conditions persisted across the Southwestern Region in 2020-2021. This severe and acute drought stress incited severe dieback and mortality of juniper. Forest Health Protection staff are monitoring the effects of drought on juniper dieback and mortality across portions of Arizona and New Mexico (Figure 47). As part of these efforts, they are working with the Forest Service Geospatial Technology and Applications Center (GTAC) to validate remote sensing products (DeltaViewer) that are being developed to show the extent and severity of juniper damage. Arizona Zone FHP staff also are assessing individual tree health to determine if juniper exhibiting drought effects from aerial surveys and in remotely sensed imagery were dying outright or only experiencing severe dieback. The goal was to assess juniper trees of different sizes exhibiting a range of dieback, but generally greater than 50 percent. New growth was observed on more than 60 percent of junipers experiencing severe dieback across the Coconino, Kaibab, and Prescott National Forests in October 2021. Trees will be re-assessed annually for the next several years to determine if they die or survive. *For more information, contact Joel McMillin.*

Figure 47. Installing transects to monitor individual juniper tree dieback and mortality, Coconino National Forest.

Biological Evaluations and Technical Assistance

Arizona Zone

Arizona Department of Forestry and Fire Management and USDA FS, Southwestern Region Arizona Zone. 2021. Arizona, Forest Health Alert, Oystershell Scale Crawlers Emerging in Northern and Central Arizona, May 2021.

DePinte, D., Grady A.M., Gaylord M.L., McMillin J.D., and Wilhelmi, N. 2021 Forest Health Conditions and Recommendations for the Pinaleño FireScape Project on the Safford Ranger District, Coronado National Forest. AZ-FHP-21-5.

Gaylord, M.L. 2021. Bark beetle activity on the Kaibab National Forest Williams Ranger District. AZ-FHP-21-01.

Gaylord, M.L. 2021. Biological Evaluation of Bark Beetle Activity and Impacts within the Frye Fire in 2021. AZ-FHP-21-08.

Gaylord, M.L, Wilhelmi, N. and McMillin, J.D. 2021. Biological Evaluation for Dairy Springs Project, Flagstaff Ranger District, Coconino National Forest. AZ-FHP-21-09.

Gaylord, M.L. 2021. Biological Evaluation of Bark Beetle Activity and Recommendations for Bear Canyon in 2021, Santa Catalina Ranger District, Coronado National Forest. AZ-FHP-21-10.

Gaylord, M.L. 2021. Biological Evaluation of Bark Beetle Activity and Impacts within the Bighorn Fire in 2021, Santa Catalina Ranger District, Coronado National Forest. AZ-FHP-21-11.

Gaylord, M.L. 2021 Bark Beetle Activity in the Clover Timber Sale on the Kaibab National Forest, Williams Ranger District. AZ-FHP-21-12.

Gaylord, M.L. 2021. Evaluation of Spruce Beetle Activity on the Springerville Ranger District, Apache-Sitgreaves National Forest, 2021. AZ-FHP-21-13.

Gaylord, M.L. 2021. Apache-Sitgreaves National Forest. 2021 Insect and Disease Aerial Survey Results.

Gaylord, M.L. 2021. Prescott National Forest. 2021 Insect and Disease Aerial Survey Results.

Gaylord, M.L. 2021. Coconino National Forest. 2021 Insect and Disease Aerial Survey Results.

Gaylord, M.L. 2021. Kaibab National Forest. 2021 Insect and Disease Aerial Survey Results.

Grady, A.M. 2021. Gypsy moth trapping results for Arizona in 2021. Letter to APHIS-PPQ.

Grady, A.M. 2021. Douglas-fir tussock moth trapping results for Arizona in 2021. Letter to Forest Silviculturists.

Grady, A.M. 2021. San Carlos Apache Tribal Lands. 2021 Insect and Disease Aerial Survey Results.

Grady, A.M. 2021. White Mountain Apache Tribal Lands. 2021 Insect and Disease Aerial Survey Results.

Grady, A.M. 2021. Navajo Nation Tribal Lands. 2021 Insect and Disease Aerial Survey Results.

Grady, A.M. 2021. Hopi Tribal Lands. 2021 Insect and Disease Aerial Survey Results.

Grady, A.M. 2021. Hualapai Tribal Lands. 2021 Insect and Disease Aerial Survey Results.

McMillin, J.D. 2021. Assessment of Planned Prescribed Burn Treatments in Upper Beaver Creek Forest Health Project, Mogollon Rim Ranger District, Coconino National Forest. AZ-FHP-21-03.

McMillin, J.D. 2021. Camp Navajo. 2021 Insect and Disease Aerial Survey Results.

McMillin, J.D. 2021. Canyon de Chelly National Monument. 2021 Forest Insect and Disease Aerial Survey Results.

McMillin, J.D. 2021. Grand Canyon National Park. 2021 Forest Insect and Disease Aerial Survey Results.

McMillin, J.D. 2021. Flagstaff Area National Monuments. 2021 Forest Insect and Disease Aerial Survey Results.

Wilhelmi, N. 2021. Chiricahua National Monument. 2021 Insect and Disease Aerial Survey Results.

Wilhelmi, N. 2021. Flagstaff Area National Monuments. 2021 Insect and Disease Aerial Survey Results.

Wilhelmi, N. 2021. Fort Huachuca. 2021 Insect and Disease Aerial Survey Results.

Wilhelmi, N. 2021. Saguaro National Park. 2021 Insect and Disease Aerial Survey Results.

Wilhelmi, N. 2021. Tonto National Forest. 2021 Insect and Disease Aerial Survey Results.

Wilhelmi, N. 2021. Assessment of Oak Defoliation on the Nogales Ranger District, Coronado National Forest. AZ-FHP-21-04.

Wilhelmi, N. 2021. Assessment of Oak Mortality on Pleasant Valley Ranger District, Tonto National Forest. AZ-FHP-21-06.

Wilhelmi, N. 2021. Biological Evaluation for Camp Navajo, Arizona Army National Guard. AZ-AZ-FHP-21-07.

New Mexico Zone

Reynolds, G.J. 2021. Evaluation of a proposed FY2022 Forest Health Suppression Project on San Felipe Pueblo Tribal Lands. Biological Evaluation. NM-FHP-9-21.

Reynolds, G.J. and Souder, S.K. 2021. Insect and disease evaluation for forested lands on Los Alamos National Laboratory. Biological Evaluation. NM-FHP-8-21.

Reynolds, G.J. and Souder, S.K. 2021. Evaluation of pinyon mortality on Ramah Navajo Tribal Lands. Biological Evaluation. NM-FHP-7-21.

Reynolds, G.J. and Souder, S.K. 2021. Evaluation of western spruce budworm and other forest health issues on the Sacramento Ranger District, Lincoln National Forest. Biological Evaluation. NM-FHP-6-21.

Reynolds, G.J. 2021. Evaluation of proposed FY2022 Forest Health Suppression Project on the Santa Clara Pueblo. Biological Evaluation. NM-FHP-5-21.

Reynolds, G.J. and Souder, S.K. 2021. Evaluation of root disease and other forest health issues in two stands on the Tres Piedras Ranger District, Carson National Forest. Biological Evaluation. NM-FHP-4-21.

Reynolds, G.J. 2021. Hazard tree issues on Aztec Ruins National Monument. Biological Evaluation. NM-FHP-3-21.

Reynolds, G.J. and Souder, S.K. 2021. Evaluation of forest health issues in and around Santa Clara Canyon for Santa Clara Pueblo. Biological Evaluation. NM-FHP-2-21.

Reynolds, G.J. and Souder, S.K. 2021. Forest health issues on Carrizo Mountain, Smokey Bear Ranger District, Lincoln National Forest. Biological Evaluation. NM-FHP-1-21.

Ryerson, D. and Tischler, C. 2021. BLM Lands in New Mexico. 2021 Insect and Disease Survey Results.

Ryerson, D. and Tischler, C. 2021. Carson National Forest. 2021 Insect and Disease Survey Results.

Ryerson, D. and Tischler, C. 2021. Central New Mexico Tribal Lands. 2021 Insect and Disease Survey Results.

Ryerson, D. and Tischler, C. 2021. Cibola National Forest. 2021 Insect and Disease Survey Results.

Ryerson, D. and Tischler, C. 2021. Gila National Forest. 2021 Insect and Disease Survey Results.

Ryerson, D. and Tischler, C. 2021. Lincoln National Forest. 2021 Insect and Disease Survey Results.

Ryerson, D. and Tischler, C. 2021. Mescalero Apache Tribal Lands. 2021 Insect and Disease Survey Results.

Ryerson, D. and Tischler, C. 2021. Northern New Mexico Tribal Lands. 2021 Insect and Disease Survey Results.

Ryerson, D. and Tischler, C. 2021. National Park Lands in the Jemez Mountains. 2021 Insect and Disease Survey Results.

Ryerson, D. and Tischler, C. 2021. Santa Fe National Forest. 2021 Insect and Disease Survey Results.

Souder, S.K. 2021. *Lymantria dispar* trapping results for New Mexico in 2021. Letter to APHIS-PPQ.

Souder, S.K. 2021. Douglas-fir tussock moth trapping results for New Mexico in 2021. Letter to Forest Supervisors.

Peer-reviewed Publications

Audley, J.P, Fettig, C.J., Munson, A.S., Runyon, J.B., Mortenson, L.A., Steed, B.E., Gibson, K.E., Jørgensen, C.L., McKelvey, S.R., **McMillin, J.D.**, and Negrón, J.F. 2021. Dynamics of beetle-killed snags following mountain pine beetle outbreaks in lodgepole pine forests. Forest Ecology and Management 482:118870. https://doi.org/10.1016/j.foreco.2020.118870.

Crouch, C.D., **Grady, A.M**., **Wilhelmi, N.P**., Hofstetter R.H., DePinte, D.E., and Waring K.M. 2021. Oystershell scale: an emerging invasive threat to aspen in the southwestern US. Biological Invasions 23:2893–2912. https://doi.org/10.1007/s10530-021-02545-0.

Sullivan, B.T., **Grady, A.M**., Hofstetter, R.W., Pureswaran, D.S., Brownie, C., Cluck, D., Coleman, T.W., **Graves, A**., Willhite, E., Spiegel, L., and Scarbrough, D. 2021. Evidence for semiochemical divergence between sibling bark beetle species: *Dendroctonus brevicomis* and *Dendroctonus barberi*. Journal of Chemical Ecology 47(1):10-27. https://doi.org/10.1007/s10886-020-01233-y.

Wilhelmi, N., Bennett, P.I., Shaw, D.C., and Stone, J.K. 2021. Rhabdocline Needle Cast of Douglas-fir. Forest Insect & Disease Leaflet 190. USDA Forest Service, Washington, DC. 20 p.

Wright S.A., Lalande B., **Wilhelmi N**., and Stewart J.E. 2021. First report of *Biscogniauxia mediterranea* on *Quercus emoryi* in southern Arizona. Plant Disease 106:1305. https://doi.org/10.1094/PDIS-09-21-1933-PDN.

Conference Proceedings

Dobbs, J., Kim, M.S., **Reynolds, G.J.**, **Wilhelmi, N.**, Dumroese, R.K., Klopfenstein, N.B., Fraedrich, S., Cram, M., Bronson, J.J., and Stewart, J. 2021. Haplotype analysis of *Fusarium* spp. collected from conifer tree nurseries of the contiguous U.S.A. Phytopathology 111:S1.35-S1.36. https://doi.org/10.1094/PHYTO-111-9-S1.35.

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.

Monica Gaylord (928) 556-2074

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

Amanda Grady (928) 556-2072

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

Nicholas Wilhelmi (928) 556-2075

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

New Mexico Zone

Andrew Graves (505) 842-3287

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

Gregory J. 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. In 2022, Dan will continue to serve the Southwestern Region as a Science Delivery Specialist with the Ecosystem, Analysis, and Planning staff.

Steven Souder (505) 842-3286

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

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 (Retired) (505) 842-3280

Allen had been the regional coordinator for invasive species and pesticide-use since 2006. Duties included 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 served as the Region representative for the Biological Control of Invasive Plants (BCIP) grant program managed by the Forest Health Technology Enterprise Team (FHTET). Allen retired at the end of 2021 after serving as the regional invasives coordinator for 15 years.

Appendix: Species Index

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

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

*Pathogen scientific names are updated 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

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The Forest Service Southwestern Region Forest Health Protection provides additional information at http://www.fs.usda.gov/goto/r3/foresthealth. Technical information posted on this site includes annual forest insect and disease conditions reports, literature on pest biology and management, and general information on forest health in the Southwest. Additionally, our Forest Health Protection national office provides program overviews at http://www.fs.fed.us/foresthealth.