CHAPTER 8

Health and Abundance of Five-Needle Pines in Southern Colorado and Northern New Mexico

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INTRODUCTION

Limber pine (*Pinus flexilis*) and Rocky Mountain bristlecone pine (*P. aristata*) are ecologically important five-needle pine species in the Southern Rocky Mountains. Limber pine and southwestern white pine (*P. strobiformis*), a species native to southern New Mexico and Arizona, also hybridize across a broad zone spanning the New Mexico-Colorado border (Menon and others 2018). While none of these pines have commercial value, they are keystone species in that they provide habitat and a food source for wildlife, regulate snow retention and runoff, facilitate the establishment of late successional tree species at treeline, and maintain cover on harsh, rugged sites where few other tree species can grow (Schoettle 2004, Steele 1990).

Five-needle pine populations are declining in many parts of the Rocky Mountains, largely due to the combined impacts of the nonnative, invasive disease known as white pine blister rust (WPBR; *Cronartium ribicola*) and mountain pine beetle (MPB; *Dendroctonus ponderosae*) (Burns and others 2023, Schoettle and others 2022, Shepherd and others 2018). While mortality of pines caused by MPB has been significant in northern Colorado, very little mortality has been reported in southern Colorado and northern New Mexico (Bentz and others 2021, Burns and others 2023, Gibson and others 2008, Schoettle and Coop 2017). WPBR has only recently been detected in this area in the Sangre de Cristo Mountains (limber pine and Rocky Mountain bristlecone pine) and Wet Mountains (limber pine) of southern Colorado in 2003 (Blodgett and Sullivan 2004, Burns 2006) and on the Santa Clara Pueblo and Santa Fe National Forest (limber pine) of northern New Mexico in 2006 (Conklin and others 2009). A rangewide survey of Rocky Mountain bristlecone pine in 2010–2011 found no new outbreak areas and predominantly healthy stands (Schoettle and Coop 2017). Comprehensive surveys of limber pine in southern Colorado and northern New Mexico are lacking. The purpose of this study was to gather baseline information on the distribution, abundance, and health of five-needle pines; characterize stand structure and site conditions; and determine the extent and severity of WPBR in the study area.

METHODS

The study area extended across the range of five-needle pines in southern Colorado and northern New Mexico focusing on previously unsurveyed areas where WPBR has not been detected. Potential survey sites were identified using local knowledge, vegetation layers, and records of herbaria specimens from SEINet (https://swbiodiversity.org/seinet/). Plots were established following the methods of Burns and others (2011).

Site data collected included geospatial coordinates, elevation, aspect, slope, slope position, stand structure, stand type (Rocky Mountain bristlecone pine, limber pine, or both species), disturbances, and the presence of alternate WPBR hosts (currants and gooseberries (*Ribes* spp.), Indian paintbrush (*Castilleja* spp.), and louseworts (*Pedicularis* spp.)). Data collected for all trees (≥4.5 feet tall) included species, diameter at breast

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height (d.b.h.; 4.5 feet), health status (healthy, declining, dying, recent dead, or old dead), crown class, and damages and their severities. Additional data collected for five-needle pines included live crown ratio (percent), recent canopy kill (percent), presence of mature green cones, and signs and symptoms of WPBR. This study did not attempt to distinguish between limber pine and limber-southwestern white pine hybrids and refer to both as limber pine for the purpose of this study. Approximately five dominant or codominant trees, including at least two five-needle pines, were cored at each site to determine stand age structure. Within each plot, three circular, fixed-area subplots (1/100 acre, 11.8-foot radius) were installed at equal increments along the transect line. Within each subplot, ground cover was estimated as percentage of bare soil, vegetation, lichen and moss, rock, litter, and trees and logs. Additionally, regeneration (<4.5 feet tall) was tallied by species and WPBR presence/absence for five-needle pines. Five-needle pine regeneration was also tallied across the entire plot. To cover as much ground as possible, researchers also conducted walk-through transects along roads adjacent to formally surveyed sites, which consisted of examining and tallying all five-needle pines by species and WPBR status within 25 feet perpendicular to the measured transect line in both directions. Data analyses were conducted using SAS software.

RESULTS

Site and Stand Characteristics

Fifty-eight plots were established in 2018–2019 on the Rio Grande (34), Carson (8), San Juan (3), and Gunnison National Forests (8), and along the eastern edge of the San Luis Valley in Great Sand Dunes National Park and Preserve and private land (5) (fig. 8.1). Limber pine occurred in 47 plots and Rocky Mountain bristlecone pine occurred in 26. Researchers examined 4,016 trees (3,372 live) within plots including 621 (602 live) limber pines and 722 (688 live) Rocky Mountain bristlecone pines. Plots ranged in elevation from 8,087 to 11,580 feet and were 9,671 feet on average. Most plots were on middle (47 percent) and upper (42 percent) slope positions and the majority were on south-facing slopes (45 percent). Average slope was 17 degrees (range 1–43). *Ribes* spp. occurred on 53 percent, *Castilleja* spp. on 17 percent, and *Pedicularis* spp. on 7 percent of plots. Wax currant (*R. cereum*) was the most common *Ribes* spp. followed by whitestem gooseberry (*R. inerme*), gooseberry currant (*R. montigenum*), and Mescalero currant (*R. mescalerium*). The most common site disturbance observed was fire with 41 percent of sites exhibiting evidence of previous fire.

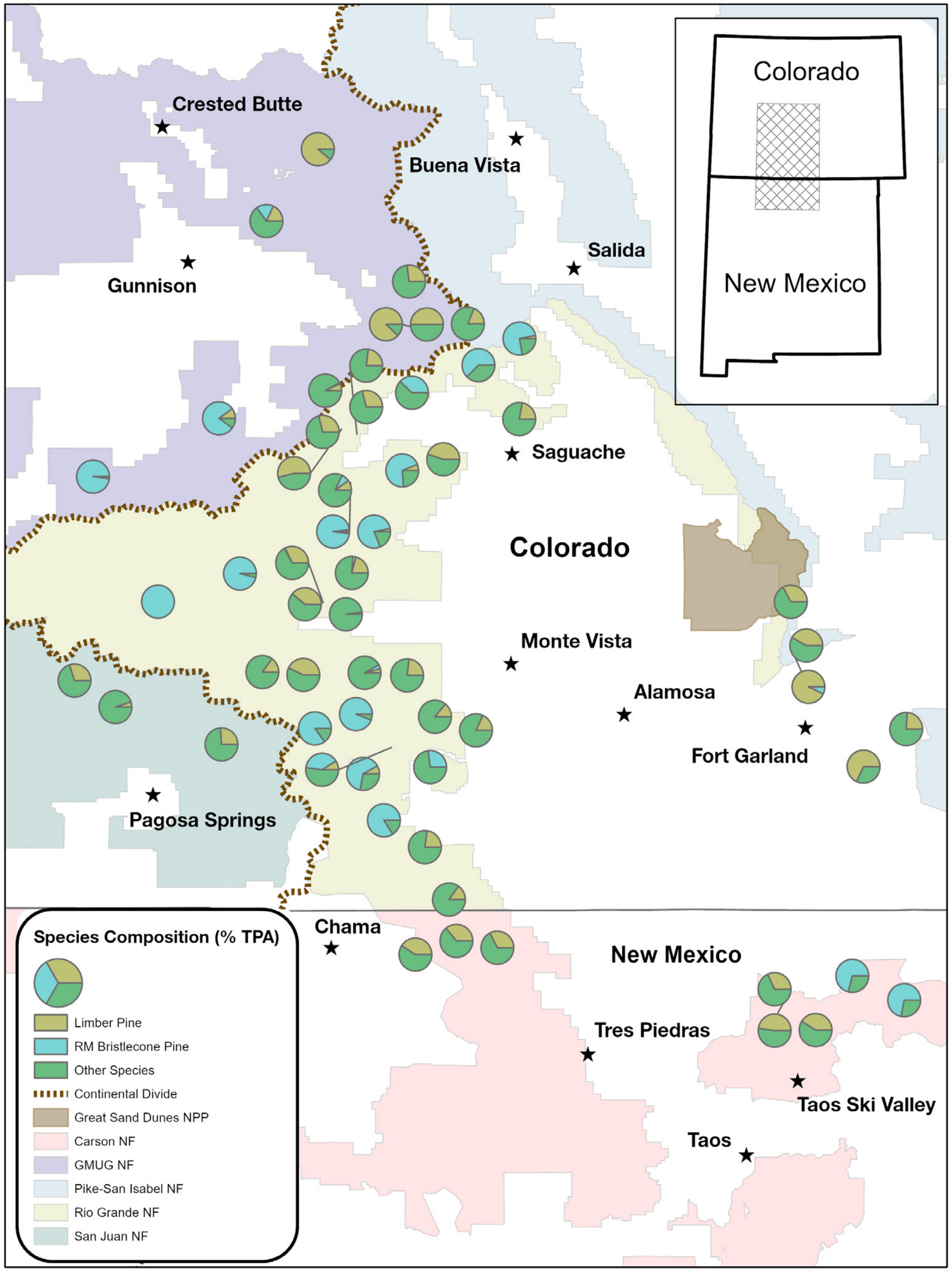

Figure 8.1—Locations of 58 limber pine and Rocky Mountain bristlecone pine health monitoring plots in southern Colorado and northern New Mexico. Pie charts represent species composition based on percentage of trees per acre made up of limber pine (dark green), Rocky Mountain bristlecone pine (light green), and other species (magenta). NF = National Forest; NPP = National Park and Preserve; RM = Rocky Mountain; TPA = trees per acre.

Live tree density of all species was 253 (range 52–1,279) trees per acre on average. Limber pine occurred as a smaller component of mixed species stands than Rocky Mountain bristlecone pine (table 8.1). In stands with limber pine, quaking aspen (*Populus tremuloides*) was the most abundant species followed by limber pine, Douglas-fir (*Pseudotsuga menziesii*), Rocky Mountain bristlecone pine, Engelmann spruce (*Picea engelmannii*), white fir (*Abies concolor*), and ponderosa pine (*Pinus ponderosa*). Rocky Mountain bristlecone pine was the most abundant species in stands where it occurred, followed by quaking aspen, Douglas-fir, limber pine, Engelmann spruce, white fir, and ponderosa pine. Stand basal area for trees was 79 (range 15–210) square feet per acre on average. Both five-needle pine species contributed the most to basal area where they occurred with Rocky Mountain bristlecone pine making up 53 percent and limber pine 38 percent of basal area on average (table 8.2). Average d.b.h. was 8.2 and 6.1 inches for limber pine and Rocky Mountain bristlecone pine, respectively. While quaking aspen was abundant, it only contributed 8 percent to total basal area and d.b.h. was only 3.6 inches on average. Other than five-needle pines, Douglas-fir contributed the most to basal area in all stands (table 8.2). Most stands were intermediate in age with limber pines being 168 (range 46–388) and Rocky Mountain bristlecone pines 207 (range 68–383) years old on average. The oldest trees were Douglas-firs, which were approximately 550 years old.

Five-needle pine regeneration was present in only 69 percent of all surveyed stands and 17 percent had no regeneration of any species. Plots had 18.5 five-needle pine seedlings per acre on average. Unlike what others have reported, this study found no relationships between five-needle pine regeneration density and stand or site factors (Cleaver and others 2016, Schoettle and Coop 2017). The most abundant regenerating species were quaking aspen and Douglas-fir. WPBR was not detected on regeneration within plots. Active cone production was found on 15.8 percent and 18.6 percent of all live limber pines and Rocky Mountain bristlecone pines, for an average of 7.1 and 9.6 cone-bearing limber pines and Rocky Mountain bristlecone pines per acre, respectively. Cone production was light during both years, and neither was a mast year.

Table 8.1—Comparison of live tree density (trees per acre ≥4.5 feet tall) by species between all sites and sites where limber pine and Rocky Mountain bristlecone pine occurred

	All sites				Sites with limber pine[a]				Sites with Rocky Mountain bristlecone pine[b]			
Species	**#[c]**	**Mean TPA (SD)**	**Range**	**% of TPA**	**#[c]**	**Mean TPA (SD)**	**Range**	**% of TPA**	**#[c]**	**Mean TPA (SD)**	**Range**	**% of TPA**
Limber pine	47	45 (40)	0–135	18%	47	56 (37)	4–132	21%	15	22 (36)	0–126	8%
Rocky Mountain bristlecone pine	26	52 (90)	0–365	21%	15	25 (62)	0–305	10%	26	115 (104)	4–365	40%
Quaking aspen	28	73 (183)	0–1,183	29%	25	85 (200)	0–1,183	33%	12	84 (265)	0–1,183	30%
Douglas-fir	39	41 (58)	0–278	16%	34	45 (59)	0–278	17%	13	37 (75)	0–278	13%
Engelmann spruce	30	16 (25)	0–109	6%	26	17 (26)	0–109	7%	15	17 (26)	0–78	6%
Ponderosa pine	21	10 (17)	0–78	4%	18	10 (17)	0–78	4%	7	7 (14)	0–48	2%
White fir	11	9 (27)	0–131	4%	11	11 (30)	0–131	4%	2	2 (10)	0–52	1%
Other[d]	12	8 (27)	0–139	3%	13	9 (29)	0–139	4%	7	1 (2)	0–9	0%
Overall	58	253 (203)	52–1,279	—	47	260 (219)	57–1,279	—	26	286 (242)	52–1,279	—

SD = standard deviation; TPA = trees per acre.

[a] Includes all plots with at least one limber pine.

[b] Includes all plots with at least one bristlecone pine.

[c] The number of plots where the species occurred.

[d] Other species include Rocky Mountain juniper (*Juniperus scopulorum*), twoneedle pinyon (*Pinus edulis*), lodgepole pine (*P. contorta*), and narrowleaf cottonwood (*Populus angustifolia*).

Table 8.2—Comparison of live tree basal area (square feet per acre ≥4.5 feet tall) by species between all sites and sites where limber pine and bristlecone pine occurred

	All sites				Sites with limber pine[a]				Sites with Rocky Mountain bristlecone pine[b]			
Species	#[c]	Mean BA (SD)	Range	% of BA	#[c]	Mean BA (SD)	Range	% of BA	#[c]	Mean BA (SD)	Range	% of BA
Limber pine	47	24 (35)	0–178	30%	47	30 (36)	0.1–178	38%	15	14 (34)	0–170	18%
Rocky Mountain bristlecone pine	26	18 (31)	0–123	23%	15	9 (25)	0–123	12%	26	39 (37)	0.1–123	53%
Quaking aspen	28	6 (11)	0–50	8%	25	6 (12)	0–50	8%	12	5 (8)	0–26	6%
Douglas-fir	39	14 (19)	0–64	18%	34	16 (20)	0–64	19%	13	10 (17)	0–64	13%
Engelmann spruce	30	5 (10)	0–37	6%	26	5 (10)	0–37	7%	15	3 (4)	0–18	3%
Ponderosa pine	21	6 (13)	0–59	8%	18	6 (13)	0–59	8%	7	4 (10)	0–40	6%
White fir	11	3 (12)	0–66	4%	11	4 (13)	0–66	5%	2	0.1 (0.5)	0–3	0%
Other[d]	12	2 (10)	0–62	3%	13	3 (11)	0–62	4%	7	0.2 (0.5)	0–2	0%
Overall	58	79 (40)	15–210	—	47	80 (43)	19–210	—	26	74 (38)	15–172	—

BA = basal area; SD = standard deviation.

[a] Includes all plots with at least one limber pine.

[b] Includes all plots with at least one bristlecone pine.

[c] The number of plots where the species occurred.

[d] Other species include Rocky Mountain juniper (*Juniperus scopulorum*), twoneedle pinyon (*Pinus edulis*), lodgepole pine (*P. contorta*), and narrowleaf cottonwood (*Populus angustifolia*).

Current Health Status of Surveyed Trees

Most five-needle pine trees surveyed were healthy, with over 90 percent of limber pines and 80 percent of Rocky Mountain bristlecone pines having no or very minor damages. The most common damages on limber pine were animal damage and twig beetles. Twig beetles were the most common damage agent in Rocky Mountain bristlecone pine followed by animal damage and fire. Less-common damages observed in both species included bark beetles (*Ips* spp. and MPB), cytospora canker (*Cytospora* spp.), western gall rust (*Endocronartium harknesii*), needle cast (*Bifusella* spp.), and WPBR. Dwarf mistletoe (*Arceuthobium cyanocarpum*) was identified on only one Rocky Mountain bristlecone pine. Mean percent recent canopy kill was significantly greater (p <0.0001) in Rocky Mountain bristlecone pine (12.5±0.5) than limber pine (5.6±0.4) and was positively correlated with percent ground cover of bare soil, Rocky Mountain bristlecone pine basal area, and d.b.h. and negatively correlated with limber pine basal area and northerly aspect. Much of the dieback was associated with twig beetles, but many trees had no obvious cause. Incidence of WPBR in plots was very low (<1 percent). All infected trees detected within formal plots were limber pines located in Great Sand Dunes National Park and Preserve (fig. 8.2). Limber pine health status was negatively correlated with slope and ground cover dominated by vegetation and rock.

Overall, 644 dead trees (>4.5 feet tall) were surveyed (16 percent of all trees) and only a small portion of these were Rocky Mountain bristlecone pine (5 percent) or limber pine (3 percent). Most mortality was quaking aspen (61 percent), Engelmann spruce (17 percent), or Douglas-fir (9 percent). Of the 15 recently killed five-needle pines, 6 were killed by bark beetles (MPB and *Ips* spp.). No signs or symptoms of WPBR were evident on surveyed snags.

Walk-Through Transects

Twenty-five walk-through transects (fig. 8.2), averaging 1.2 miles long, were completed and included observations of an additional 2,187 limber pines and 1,154 Rocky Mountain bristlecone pines. WPBR was detected at two new locations (fig. 8.2).

The first new location where WPBR was detected was a riparian area on private land about 35 miles east of Alamosa, CO, and 25 miles southeast of the previously described outbreak near Mosca Pass, CO (Blodgett and Sullivan 2004, Burns 2006). WPBR was confirmed on whitestem gooseberry and both limber pine and Rocky Mountain bristlecone pine at this site. Overall, 47 percent of trees were infected with WPBR and incidence was higher in limber pine (18 of 29 trees) than Rocky Mountain bristlecone pine (3 of 16 trees). Infected trees had five cankers on average and no rust-caused mortality was detected. This is only the second location where WPBR has been confirmed on Rocky Mountain bristlecone pine within its natural habitat (Blodgett and Sullivan 2004).

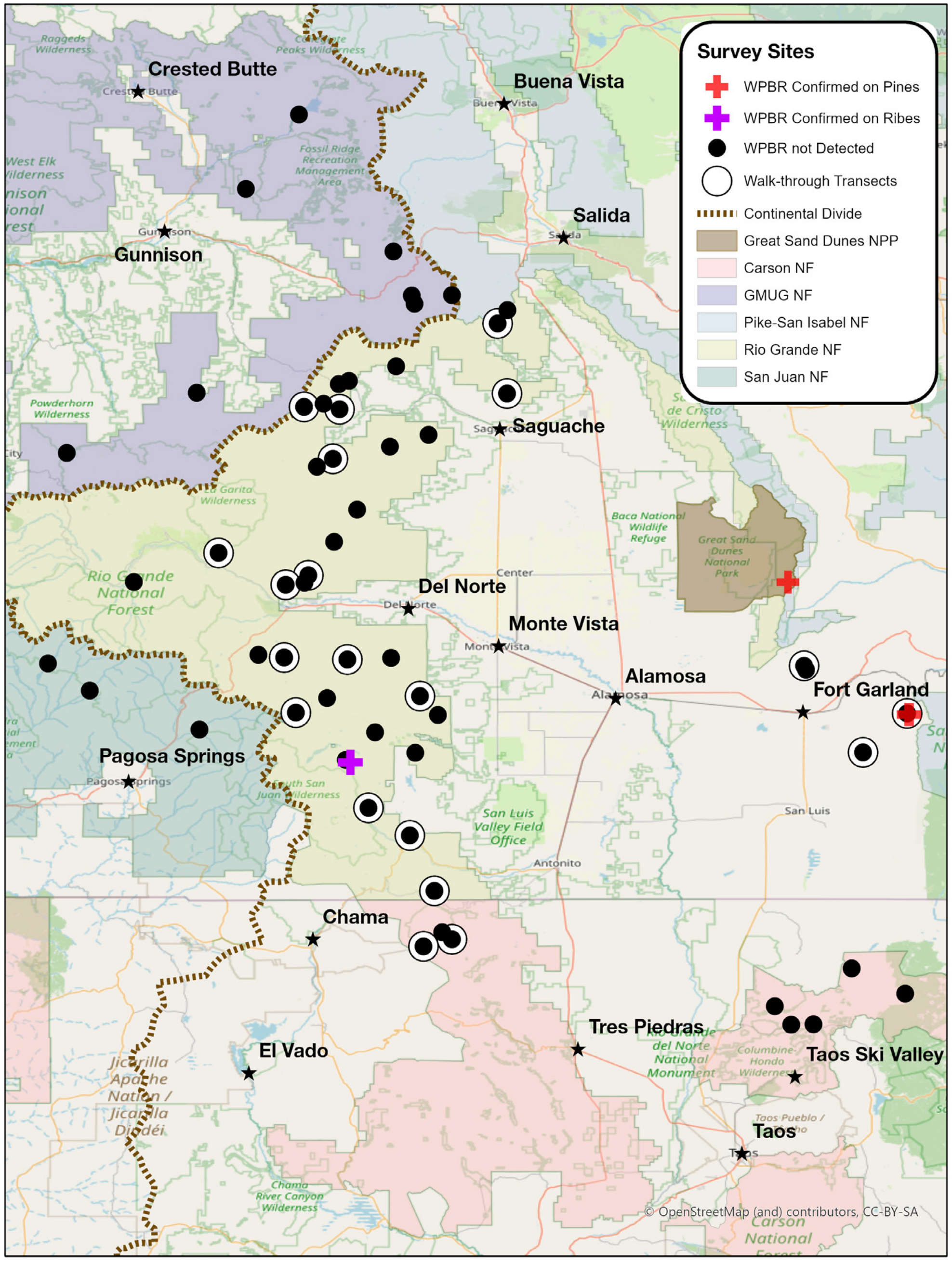

Figure 8.2—Distribution of white pine blister rust in surveyed plots, walk-through transects, and field observations. NF = National Forest; NPP = National Park and Preserve; WPBR = white pine blister rust.

The second new location where WPBR was detected was in the Lake Fork drainage, on the Conejos Peak Ranger District, Rio Grande National Forest, about 25 miles south of Del Norte, CO. An infected whitestem gooseberry bush was identified along the creek, but WPBR was not detected on surrounding pine hosts. This is roughly 60 miles west of the nearest outbreak area in Great Sand Dunes National Park and Preserve (Blodgett and Sullivan 2004, Burns 2006). Infected leaf samples were collected and submitted to a lab at Colorado State University for molecular analysis, which confirmed *Cronartium ribicola*.

DISCUSSION AND CONCLUSIONS

Limber pine and Rocky Mountain bristlecone pine are well distributed in southern Colorado and northern New Mexico but occur at lower frequencies than in other parts of their ranges (Burns and others 2023, Cleaver and others 2015, Schoettle and Coop 2017, Smith and others 2013). Density of live limber pine trees of 56 stems per acre observed in this study was considerably lower than the 126 stems per acre that Cleaver and others (2015) reported from 508 measured plots in northern Colorado, Wyoming, and Montana. However, basal area (square feet per acre) of live limber pine was slightly higher in this study (30 vs. 25 square feet per acre, respectively), indicating that limber pines, while less frequent, were larger on average. This could be explained, in part, by the low incidence of recent MPB activity in the plots. Most stands comprised non-pines, with very few pure stands of limber pine and Rocky Mountain bristlecone pine. MPB outbreaks are more likely to occur in areas with high basal area of susceptible pine hosts (Fettig and others 2007). Moreover, MPB has historically not been found attacking trees in New Mexico. Similarly, stems per acre of live Rocky Mountain bristlecone pine were considerably lower (115 stems per acre) than the 156 stems per acre Schoettle and Coop (2017) reported from 61 plots throughout the range of Rocky Mountain bristlecone pine. Live Rocky Mountain bristlecone pine basal area (39 square feet per acre) was also well below the 96 square feet per acre that Schoettle and Coop (2017) reported as the rangewide average. Most stands were mixed species with very few pure stands of either species.

Limber pines were healthier in this study than what has been reported in the northern portions of their range (Burns and others 2023, Cleaver and others 2022, Smith and others 2013). Over 90 percent of limber pines were healthy compared to only 50 percent classified as healthy in a 2016–2017 survey by Burns and others (2023). Recent mortality (1 percent), WPBR incidence (1 percent), and mortality attributed to bark beetles were also substantially lower in the southern portion of limber pine's range (compared to Burns and others 2023, Cleaver and others 2022, and Smith and others 2013). Findings were more in line with what Looney and others (2015) reported from their 2010–2011 surveys of southwestern white pine in New Mexico and Arizona. Similarly, Rocky Mountain bristlecone pines were healthier in this study compared to Schoettle and Coop's (2017) rangewide survey (80 percent vs. 71 percent, respectively).

While no new disease outbreak areas were detected in formal plots, two new infection areas were identified in walk-through surveys. *Cronartium ribicola* was confirmed on whitestem gooseberry and both limber pine and Rocky Mountain bristlecone pine approximately 25 miles southeast of the previously described outbreak in Great Sand Dunes National Park and Preserve (fig. 8.2). WPBR was also confirmed on whitestem gooseberry about 60 miles west of the park on the Rio Grande National Forest (fig. 8.2). No infected pines were detected in this area. These new outbreak areas confirm that inoculum is present and disease spread is occurring. Detection of WPBR in pine hosts is especially difficult during the early stages of invasion (Kozhar and others 2023). More frequent surveys coinciding with sporulation on pines are needed to improve estimates of disease distribution at the infection front.

Five-needle pine regeneration was found on fewer sites and at lower densities than other studies in these host types (Burns and others 2023, Cleaver and others 2016, Schoettle and Coop 2017). Burns and others (2023) reported limber pine regeneration on 76 percent of sites with an average density of 73 stems per acre. Similarly, Schoettle and Coop (2017) reported Rocky Mountain bristlecone pine regeneration averaged 60 seedlings per acre. In contrast, five-needle pine regeneration was found on only 69 percent of plots with an average density of 18.5 seedlings per acre. While Rocky Mountain bristlecone pine regeneration is common in the Rocky Mountain bristlecone pine forest type, recent studies suggest otherwise for limber pine (Goeking and Windmuller-Campione 2021). Goeking and Windmuller-Campione (2021) analyzed a large U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis dataset and found limber pine regeneration occurred more abundantly in forest types dominated by other (non-five-needle pine) species. A more thorough assessment of the distribution and abundance of regeneration is needed to determine if this is the case in southern Colorado and northern New Mexico.

The combined pressures of WPBR, bark beetles, and climate change threaten five-needle pine populations of western North America (Burns and others 2023, Kearns and others 2014, Schoettle and others 2022). Fortunately, five-needle pines, particularly limber pine, were comparatively healthy in southern Colorado and northern New Mexico. However, the lack of regeneration is concerning and suggests management intervention may be needed to stimulate recruitment on some sites. Forest management plans could include measures to increase resiliency of five-needle pines (Schoettle and others 2019a, 2019b). In areas where WPBR is not yet or only recently established, proactive silvicultural treatments may position the ecosystem to facilitate the evolution of disease resistance in tree populations before they are impacted (Schoettle and Sniezko 2007). Diversifying age class structure, by stimulating regeneration in healthy stands, will provide a larger population for resistance selection upon invasion and simultaneous selection in both the younger and older cohorts (Schoettle and others 2019a, 2019b, 2022). Periodic forest health monitoring is warranted as disease spread is likely to continue over time in the study area.

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