



# Forest Health of High-Elevation, Five-Needle Pines at Glacier National Park, Rocky Mountain National Park, and Great Sand Dunes National Park and Preserve

## *2013 Data Report*

Natural Resource Data Series NPS/ROMN/NRDS—2017/1112



ON THE COVER

Limber pine (*Pinus flexilis*) at Mills Lake in Rocky Mountain National Park. NPS/ERIN BORGMAN

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August 2017

U.S. Department of the Interior  
National Park Service  
Natural Resource Stewardship and Science  
Fort Collins, Colorado

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Please cite this publication as:

Borgman, E. 2017. Forest health of high-elevation, five-needle pines at Glacier National Park, Rocky Mountain National Park, and Great Sand Dunes National Park and Preserve: 2013 data report. Natural Resource Data Series NPS/ROMN/NRDS—2017/1112. National Park Service, Fort Collins, Colorado.

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# Executive Summary

The purpose of this report is to summarize five-needle pine (bristlecone, limber, and whitebark pines) monitoring we conducted collaboratively with Montana State University in 2013 in Glacier National Park, Rocky Mountain National Park, and Great Sand Dunes National Park and Preserve using standardized methods. We include these data in a database built for this purpose, which is available to the National Park Service (NPS) and partners through the NPS Data Store (<https://irma.nps.gov/DataStore/>). As NPS and others continue to monitor five-needle pines, these data and the database form a foundation and resource for better understanding and collaborative monitoring of these important and iconic species.

Five-needle pine trees, also known as white pines, are members of the subgenus *Strobus* that have bunches of 5 needles. As keystone species, they play a significant role in maintaining ecosystem structure, function, and biodiversity. Over the last few decades high-elevation, five-needle pine forests have endured novel stressors and disturbance, including the invasive exotic pathogen, *Cronartium ribicola*, which causes white pine blister rust, increasing mountain pine beetle (*Dendroctonus ponderosae*) activity, and changes in precipitation and temperature patterns.

The NPS Inventory and Monitoring program held a climate change workshop in 2010 entitled, “Monitoring Ecological Response to Climate Change in High Elevation Park Units of the Great Northern Landscape Conservation Cooperative.” As a result of this workshop, the NPS Rocky Mountain Inventory and Monitoring Network (hereafter, Rocky Mountain Network) partnered with Montana State University through a Rocky Mountains Cooperative Ecosystem Studies Unit cooperative agreement to monitor five-needle pine species in 3 national parks. Fieldwork was conducted in 2013 to monitor bristlecone pine (*Pinus aristata*) and limber pine (*Pinus flexilis*) trees at Great Sand Dunes National Park and Preserve, limber pine at Rocky Mountain National Park, and whitebark pine (*Pinus albicaulis*) at Glacier National Park.

Key results from monitoring include the following:

- The highest levels of blister rust infection were found in Glacier (23.7% of living trees in plots infected), followed by Great Sand Dunes (7.1%) and Rocky Mountain (0.3%).
- Evidence of mountain pine beetle activity was highest at Rocky Mountain (6.1% of five-needle pine trees in plots affected), followed by Great Sand Dunes (0.4%), and was absent from Glacier.
- There was some regeneration, as evidenced by seedlings (<1.4 m tall) in all 3 parks. Seedlings found in subplots included numerous species of pine, fir, spruce, as well as aspen and juniper. Aspen seedling density was very high (3,466 seedlings/hectare) in Great Sand Dunes and low in Glacier (68.6 seedlings/hectare). No aspen seedlings were found in our plots in Rocky Mountain.
- Dominant mature species found at each park included limber pine (Great Sand Dunes and Rocky Mountain) and subalpine fir (Glacier).

Because methods we used are standardized and similar to those used by the USDA Forest Service (USFS) and the NPS Greater Yellowstone Inventory and Monitoring Network, datasets spanning the Rocky Mountains could potentially be combined and analyses expanded to potentially reveal broad scale patterns or trends in five-needle pines in the Rocky Mountain region. To facilitate such an endeavor, the Rocky Mountain Network funded the creation of the Five-Needle Pine Monitoring Database. This relational database currently houses Rocky Mountain Network data, USFS data from the Rocky Mountains spanning Montana, Wyoming, and Colorado, and data collected by other partner organizations over the last 13 years. If future data are integrated into the database, we can explore larger-scale trends.

Due to the dynamic nature of these high-elevation forests and the stressors they currently experience, we recommend continued monitoring of five-needle pine forests. The funding for the 2013 field work described here is no longer available. However, the Rocky Mountain Network may be able to partner with others, including Glacier National Park, Rocky Mountain National Park, and Great Sand Dunes National Park and Preserve; the NPS Greater Yellowstone Inventory and Monitoring Network, and the USFS to conduct future monitoring of these valuable resources.

## Acknowledgments

We would like to thank key collaborators that helped make this project possible:

Dave Roberts, Dana Weller, Andrew Oringer, Katelynn Martinez (Montana State University); Kelly Burns, Anna Schoettle, Justin Hof (USDA Forest Service); Jennifer Asebrook

(Glacier National Park); Brian Verhulst (Rocky Mountain National Park); Phyllis Bovin (Great Sand Dunes National Park and Preserve); Donna Shorrock (Rocky Mountain I&M Network), Kristin Legg (Greater Yellowstone I&M Network); Ken Blomberg, Ben Seidle (Managed Business Solutions).

# Introduction

Participants in a National Park Service (NPS) monitoring workshop in 2010 entitled, “Monitoring Ecological Response to Climate Change in High Elevation Parks in the Great Northern Landscape Conservation Cooperative” identified five-needle pines as the highest priority vital sign for collaborative monitoring in high-elevation national parks. In 2013, through a \$16,200 cooperative agreement between the NPS Rocky Mountain Inventory and Monitoring Network (hereafter, Rocky Mountain Network) and Montana State University, we worked with Glacier National Park (GLAC), Rocky Mountain National Park (ROMO) and Great Sand Dunes National Park and Preserve (GRSA) to complete field monitoring of five-needle pines. In conjunction with that project, the Rocky Mountain Network worked with the NPS Inventory and Monitoring Division to build a database to manage five-needle pine monitoring data from this project and from historical data from these parks and the USDA Forest Service (USFS).

This is a basic data report summarizing monitoring field work done in 2013 and the five-needle pine database. We provide little context and no discussion of results or significance. In the future, the Rocky Mountain Network may analyze this dataset (ideally with additional monitoring data and with partners in the parks, the Greater Yellowstone Inventory and Monitoring Network (hereafter, Greater Yellowstone Network), USFS or others) to understand patterns in five-needle pines across the region and over time.

Five-needle pine trees, also known as white pines, are members of the subgenus *Strobus* that have bunches of 5 needles. As keystone species, they play a significant role in maintaining ecosystem structure, function, and biodiversity. They may facilitate other tree species in the harsh environments where they typically occur (Resler and Tomback 2008; Baumeister and Callaway 2006; Rebertus et al. 1991) or otherwise influence forest succession (Kinloch 2003). Five-needle pines often grow in xeric conditions where other tree species do not thrive, aiding in soil stabilization and snowpack retention. Reductions in abundance, and especially reductions in seed production, may also negatively impact several animal species, such as Clark’s nutcrackers (*Nucifraga columbiana*), numerous squirrel species (including red squirrels (*Tamiasciurus hudsonicus*)), and grizzly bears (*Ursus arctos horribilis*) (McKinney et al. 2009).

Over the last few decades high-elevation, five-needle pine forests have been subjected to novel stressors and disturbance. The invasive pathogen (*Cronartium ribicola*)

that causes white pine blister rust in five-needle pines has steadily moved up in elevation and southward from its initial infestation in the northern Rocky Mountains. White pine blister rust impacts have been severe in the northern Rocky Mountains, resulting in mortality rates for whitebark pine (*Pinus albicaulis*) as high as 90% in GLAC and other northern Rocky Mountain forests (McKinney et al. 2009). As blister rust migrates eastward and southward, it has caused slightly less severe, although still extreme, impacts. Whitebark pine mortality rates in Yellowstone are estimated to be approximately 30% to date (Shanahan et al. 2014). Blister rust has been reported in Colorado on limber pine (*Pinus flexilis*) since 1998 (Johnson and Jacobi 2000). It was confirmed in ROMO in 2010 and has been found in lands surrounding the park (Schoettle et al. 2011). Blister rust was reported on limber pine and Rocky Mountain bristlecone pine (*Pinus aristata*) in GRSA in 2003 (Blodgett and Sullivan 2004; Burns 2006). Blister rust in and around GRSA is variable, with pockets of high infection around Mosca Pass; from there the disease front extends about 7 miles north and 5 miles south (Burns 2006).

Blister rust infection results in reduced vigor. Infected branches exhibit cankers that restrict the flow of water and nutrients in the xylem and phloem. Death of infected branches is common, causing the loss of cone crops and seed as well as reduced vigor (Schwandt et al. 2010). Blister rust infections in the main stem often result in mortality, especially on smaller trees. It can also inhibit regeneration of five-needle pines by reducing available seeds and infecting even small saplings (McKinney and Tomback 2007; Tomback et al. 1995).

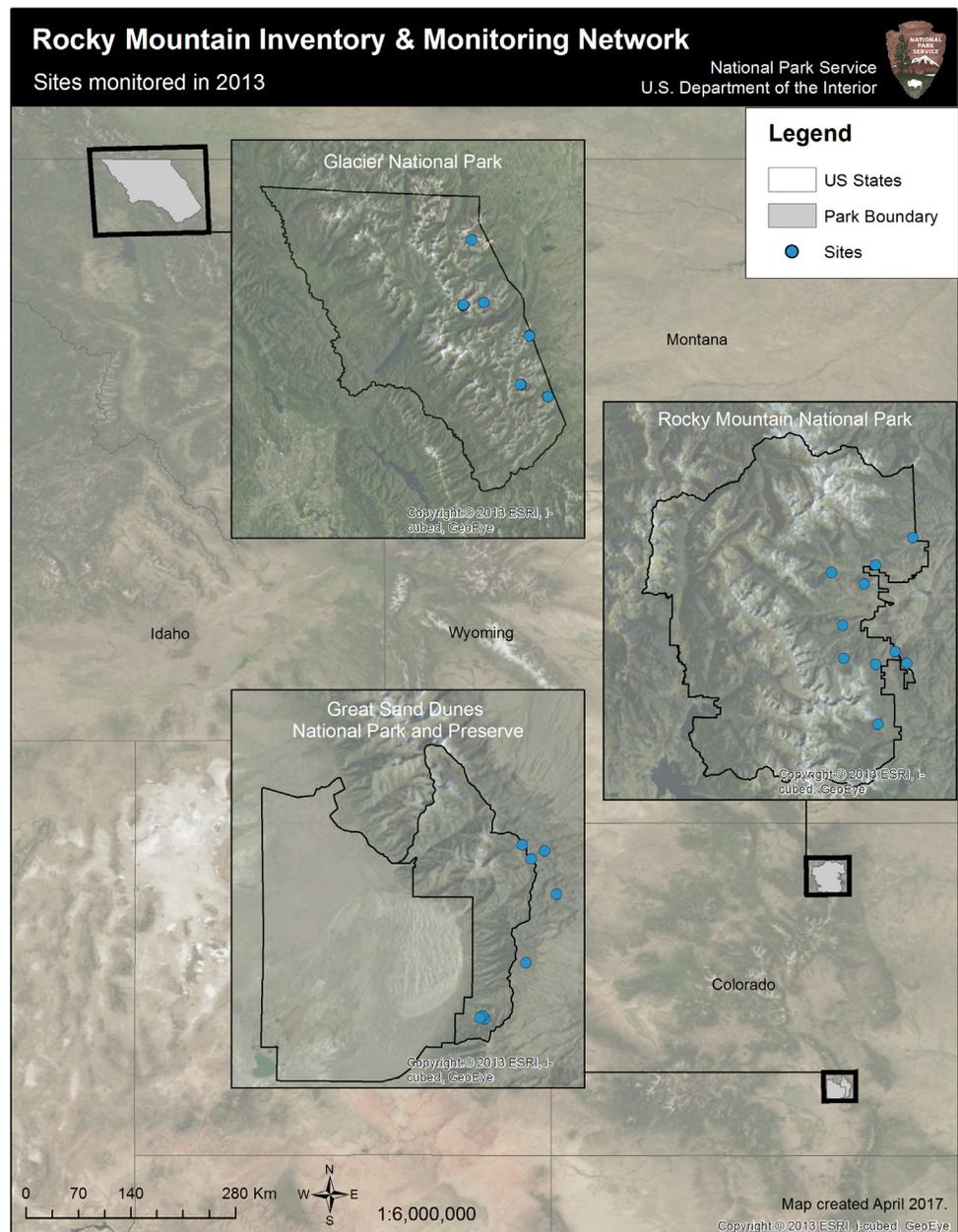
Simultaneously, mountain pine beetle (*Dendroctonus ponderosae*), a native pine bark beetle, has increasingly invaded higher elevation forests over the last few decades (Schwandt et al. 2010; Raffa et al. 2008). Pine beetle attacks on five-needle pine forests are known to have occurred historically (Brunelle et al. 2008; Perkins and Roberts 2003), but the current levels of infestation are thought to result from climate warming that makes the long cold spells required to kill bark beetle larvae less common (Logan et al. 2003). Severe infection of five-needle pines by blister rust may increase the likelihood of attack by mountain pine beetles (Bockino and Tinker 2012; Six and Adams 2007) and may reduce the tree’s ability to “pitch out” pine beetles (expel the beetle with sap), making pine beetle attacks more successful (Six and Adams 2007).

In addition, changes in precipitation and temperature associated with global climate change are expected to exacerbate the disease and insect problems of native conifers (Van Mantgem et al. 2009; Schrag et al. 2008), although five-needle pines in particular may be less susceptible than other species (Hunt et al. 2010). Throughout its range, limber pine is expected to lose 40% of its basal area by 2030, primarily from mountain pine beetle attack and secondarily from a combination of white pine blister rust and dwarf mistletoe infection (Krist et al. 2014).

## Scope of Study

Monitoring took place in 2013 at 8 sites in GRSA, 10 sites in ROMO, and 12 sites in GLAC (Figure 1). Our study sites were nonrandomly established in areas with a high density of five-needle pines. Sites at GRSA and ROMO that were previously established as part of USFS ongoing monitoring (Burns 2006; Schoettle et al. 2011) were sampled in coordination with USFS partners. In GLAC, a park that has seen widespread mortality of whitebark pine, sites were chosen based on the presence of living and healthy whitebark pine trees.

Figure 1. 2013 five-needle pine monitoring sites at Glacier National Park (top inset), Rocky Mountain National Park (middle inset) and Great Sand Dunes National Park and Preserve (bottom inset). Crews visited 12 sites in 6 locations at Glacier, 10 sites at Rocky, and 8 sites in 6 locations at Great Sand Dunes. Background imagery from ESRI, i-cubed, GeoEye (2013).



# Methods

## Field Methods

Slightly different methods were used at GRSA than at ROMO and GLAC in order to be comparable to current USFS monitoring. Montana State University crews conducted most of the field work.

### *Great Sand Dunes National Park and Preserve*

GRSA methods follow Burns (2006), which were adapted from those developed by Smith and Hoffman (2000) and the Whitebark Pine Ecosystem Foundation (Tomback et al. 2005). Plots were belt transects, approximately 15 × 60 m (50 × 200 ft), and were established along a contour with a random starting point. Transect width and length were adjusted so that approximately 30 live trees greater than 1.4 m (4.5 ft) tall were present in each plot, and plot slope, aspect, and site conditions were relatively uniform from one end of the plot to the other. A variable radius plot was established at the center point of the beginning, middle, and end of each plot to record stand composition. A fixed radius (0.001 ha; 0.003 ac) subplot was established at these same 3 points to examine regeneration composition and blister rust occurrence on host trees smaller than 1.4 m tall.

At each GRSA site, we recorded:

- elevation
- slope
- aspect
- transect length and width
- transect bearing
- stand structure
- slope position
- the 3 most common overstory species
- the 3 most common ground species
- regeneration (seedling) presence/absence for any tree species
- blister rust presence/absence on five-needle pine regeneration
- maximum needle retention for the dominant five-needle pine species on the plot
- *Ribes* species present in the plot and their density (0%, 1–6%, 7–12%, 13–25%, >25%)

For each five-needle pine within transects, we recorded:

- species name
- diameter at breast height
- total height
- tree status (healthy, declining, dying)
- crown class
- percent of the crown with cones
- number and size of blister rust cankers on branches
- distance to the main stem for the most lethal branch canker
- number, size, and location of stem cankers
- other damages and their severities

We assigned a blister rust damage severity rating to infected trees based on the distance from the bole of the tree to the nearest (most lethal) blister rust canker (Table 1).

Table 1. White pine blister rust damage severity codes used at Great Sand Dunes National Park and Preserve (from Smith and Hoffman 2000).

Severity code	Distance from the main stem	Damage
1	>24 inches	Minor
2	6–24 inches	Moderate
3	<6 inches or on main stem	Severe

### *Rocky Mountain and Glacier National Parks*

ROMO and GLAC field methods were adapted from the Greater Yellowstone Network inventory and monitoring protocol for whitebark pine (Greater Yellowstone Whitebark Pine Monitoring Working Group 2011), which was modified from the protocol of Tomback et al. (2005). Transects were 10 × 50 m. To maintain compatibility with existing data at GLAC (Smith et al. 2008), the transect was lengthened as needed to incorporate 30 living or recently dead trees. A fixed radius subplot (0.004 ha; 0.01 ac) was established at the beginning, middle, and endpoint of the transect to examine regeneration composition and blister rust occurrence on host trees smaller than 1.4 m tall. To be comparable with the protocol at GRSA, crews at ROMO and GLAC established variable radius plots at the beginning, middle, and end points of the transect to include information on stand composition. Due to the sparse nature of forests being monitored, crews set up 9 variable radius plots per transect (rather than 3, as

at GRSA) to get more data on mountain pine beetle mortality. Three were centered at the beginning, middle, and end points of the transect and each of those plots had 2 plots on either side, perpendicular to the transect, for a total of 9. The basal area factor was chosen to obtain approximately 6 to 8 in trees at each point. It was held constant in plots within each site but varied among sites. We identified “In trees” (trees visible through the prism using the chosen basal area factor) to species and measured their diameters.

In the main transect, specific measurements made for each tree greater than 1.4 m tall included:

- diameter at breast height (cm to nearest tenth)
- height class code (<5 m, 5–10 m, >10 m)
- status (live, recently dead (nongreen needles present), dead (no needles present))
- cone producing (Y or N)
- number of blister rust cankers on branches in the upper third, middle third, and lower third of the crown
- bole cankers in the upper third, middle third, and lower third of the tree
- flagging or swelling of branches
- live canopy volume by height classes
- pine beetle pitch tubes, frass, or galleries evident
- general observations

The field form we used and specific measurements we took followed the Greater Yellowstone Network protocol except that we measured trees of all species, rather than just five-needle pine species.

### *All Sites*

At all parks, blister rust was assumed if active sporulating cankers (aecia) were present or if 3 of the 5 indicators were present (flagging, swelling, roughened bark, rodent chewing, or oozing pitch). Aecia are visible during a limited window in early summer (May–July; Tomback et al. 2005) and are

a definitive method for identifying blister rust. Since they are not always visible during monitoring, other indicators can be used to suggest blister rust infection. Though using indicators is not as diagnostic as observing aecia and has the potential to overestimate blister rust infection, these methods are consistent with the monitoring protocol by the Greater Yellowstone Whitebark Pine Monitoring Working Group (2011).

Over the course of the season, some field crew turnover and attrition occurred, which may have reduced the data quality, especially at our last park sampled, GLAC. Surprising results are noted in the Results sections and should be confirmed before conclusions are drawn based on data presented here.

### **Analysis**

Percent blister rust infection was calculated for living trees only. Percent of trees affected by mountain pine beetle included trees still living and dead (presumably dead from mountain pine beetle).

Stem density of seedlings was calculated based on data from 3 regeneration subplots per transect. Subplots were 0.001 ha (0.003 ac) at GRSA and 0.004 ha (0.01 ac) at ROMO and GLAC. The stem density for each seedling species was calculated at the site level and then averaged across all sites (including sites that had no seedlings of that species).

Stand composition, as measured in prism plots, is reported here as the basal area of live trees for each species. Basal area is a common forestry metric describing the average area occupied by tree stems. To calculate basal area, the total number of trees of each species in all prism plots at a site was multiplied by the basal area factor (in most cases 10 ft<sup>2</sup>/ac, though occasionally 20 ft<sup>2</sup>/ac) and divided by the number of prism plots per transect (3 for GRSA and 9 for ROMO and GLAC). The basal area for each species was calculated at the site level and then averaged across all sites in a park (including sites that had no trees of that species). Since the prism used to calculate basal area used ft<sup>2</sup>/ac, basal area is reported in the same units here.

# Results

This is a basic data report summarizing monitoring work done in GLAC, ROMO, and GRSA in 2013. Results are only applicable to the sites sampled and do not have parkwide inference.

We provide little context and no discussion of results or significance. What is presented here is a foundation; with future collaboration it would be possible to expand monitoring and explore patterns and trend in five-needle pine forests. We summarize our findings for tree size and cone production, mortality, regeneration, and forest stand composition in the following sections.

## Tree Size and Cone Production

The mean diameter at breast height of living, mature five-needle pines varied by park and ranged from 20 to 35 cm (Table 2). Few of these trees were cone producing. GLAC whitebark pine trees had the most cones, at 14% of trees sampled, followed by bristlecone pines in GRSA, at 5.78%. Five-needle pines tend to have a big cone producing year (“mast” year), followed by many years with little cone production (Tomback 1982); 2013 did not appear to be a mast year in any park sampled. Other factors like predation from cone and seed insects can also affect cone production (Schoettle and Negron 2001).

## Mortality

At GRSA, 5.4% of the sampled limber pine trees were dead, 7.1% had evidence of blister rust infection, and 0.4% were

affected by mountain pine beetles (Table 3). There were no dead bristlecone pine trees, and no live bristlecone pines with sign of blister rust or mountain pine beetle. At ROMO a larger percentage of limber pine trees was dead (12.7%), there was less evidence of blister rust (0.3%), and a larger percentage (6.1%) was affected by mountain pine beetle. ROMO had only one tree with indicators of blister rust, though no visible aecia were present. This tree should be re-evaluated during future monitoring to determine if blister rust is indeed present. At GLAC, all sampled whitebark pine trees were living, there was a much higher incidence of blister rust (23.7%) than at the other 2 parks, and there was no evidence of mountain pine beetle. Though healthy stands were chosen for monitoring at GLAC, it is surprising that we documented no dead whitebark pines. This finding should be confirmed if monitoring is repeated.

## Regeneration

All parks had some regeneration of seedlings. Seedlings found in subplots included numerous species of pine, fir, spruce, as well as aspen and juniper (Table 4; Figure 2). Aspen regeneration was very high at 2 GRSA sites in the Medano Pass area, likely because of a recent wildfire, whereas other sites at GRSA had no aspen regeneration. Though no bristlecone seedlings were found in regeneration subplots at GRSA, several sites had bristlecone seedlings present. Variation was high between sites for many seedling species; some sites had more recruitment than others.

Table 2. Mean diameter at breast height, with standard deviation, and percentage of trees with cones at the time of sampling for living five-needle pines at Glacier National Park (GLAC), Great Sand Dunes National Park and Preserve (GRSA), and Rocky Mountain National Park (ROMO) in 2013.

Park	Pine tree species	Mean diameter (cm)	Standard deviation (cm)	% Cone producing
GLAC	whitebark	29.31	22.75	14.14
GRSA	bristlecone	20.64	12.56	5.78
GRSA	limber	20.24	18.88	1.90
ROMO	limber	34.78	26.87	1.32

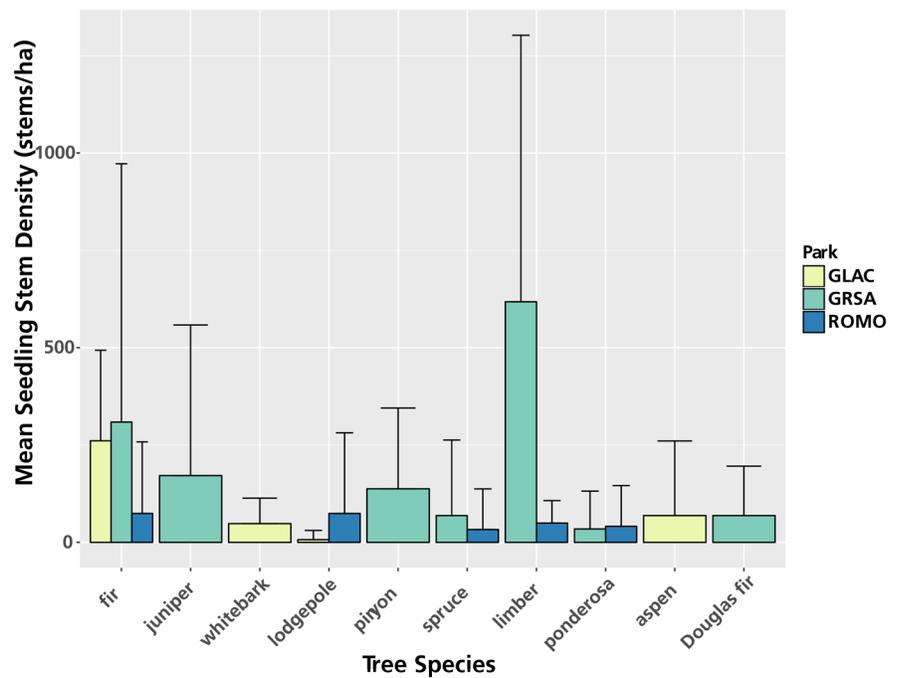
Table 3. Five-needle pine tree health at sampled stands in 2013 for Great Sand Dunes National Park and Preserve (GRSA), Rocky Mountain National Park (ROMO), and Glacier National Park (GLAC).

Park	Pine tree species	# Trees sampled	# Trees living	% Trees dead	% Trees with blister rust (of living trees)	% Affected by mountain pine beetle (of all trees)
GRSA	bristlecone	52	52	0	0	0
GRSA	limber	224	212	5.4	7.1	0.4
ROMO	limber	346	302	12.7	0.3	6.1
GLAC	whitebark	198	198	0	23.7	0

Table 4. Mean stem density of seedlings at Great Sand Dunes National Park and Preserve (GRSA), Rocky Mountain National Park (ROMO), and Glacier National Park (GLAC) in 2013.

Park	Tree species	Mean stem density (seedlings/ha)	Standard deviation
GRSA	Colorado pinyon pine ( <i>Pinus edulis</i> )	137.28	207.55
	Douglas fir ( <i>Pseudotsuga menziesii</i> )	68.64	127.10
	Engelmann spruce ( <i>Picea engelmannii</i> )	68.64	194.14
	Limber pine ( <i>Pinus flexilis</i> )	617.76	684.44
	Ponderosa pine ( <i>Pinus ponderosa</i> )	34.32	97.07
	Quaking aspen ( <i>Populus tremuloides</i> )	3466.34	6428.89
	Rocky Mountain juniper ( <i>Juniperus scopulorum</i> )	171.60	386.55
	Subalpine fir ( <i>Abies lasiocarpa</i> )	308.88	663.47
ROMO	Engelmann spruce	32.95	104.19
	Limber pine	49.42	57.59
	Lodgepole pine ( <i>Pinus contorta</i> )	74.13	207.11
	Ponderosa pine	41.18	104.55
	Subalpine fir	74.13	183.98
GLAC	Lodgepole pine	6.86	23.78
	Quaking aspen	68.64	191.84
	Subalpine fir	260.83	232.53
	Whitebark pine ( <i>Pinus albicaulis</i> )	48.05	65.32

Figure 2. The mean stem density with standard deviation of all seedlings <1.4 m tall found in subplots at Glacier National Park (GLAC; yellow), Great Sand Dunes National Park and Preserve (GRSA; green), and Rocky Mountain National Park (ROMO; blue) in 2013. Note: this figure does not include aspen at GRSA because it was so much higher than other species (see Table 4). Large error bars reflect the variation in regeneration among sites at a park. Species include subalpine fir (*Abies lasiocarpa*), Rocky Mountain juniper (*Juniperus scopulorum*), whitebark pine (*Pinus albicaulis*), lodgepole pine (*Pinus contorta*), Colorado pinyon pine (*Pinus edulis*), Engelmann spruce (*Picea engelmannii*), limber pine (*Pinus flexilis*), ponderosa pine (*Pinus ponderosa*), quaking aspen (*Populus tremuloides*), and Douglas fir (*Pseudotsuga menziesii*).



## Forest Stand Composition

Stand composition (trees >1.4 m tall) was also quite variable at sites and included firs, spruces, and pines (Figure 3). Limber pine was dominant at both GRSA and ROMO (largely because monitoring locations were chosen for their high

density of five-needle pine trees). Subalpine fir was most dominant at GLAC. It is surprising that no whitebark pine trees were recorded in subplots at GLAC, though it is possible if stands were sparse. This finding should be confirmed if sites are monitored again.

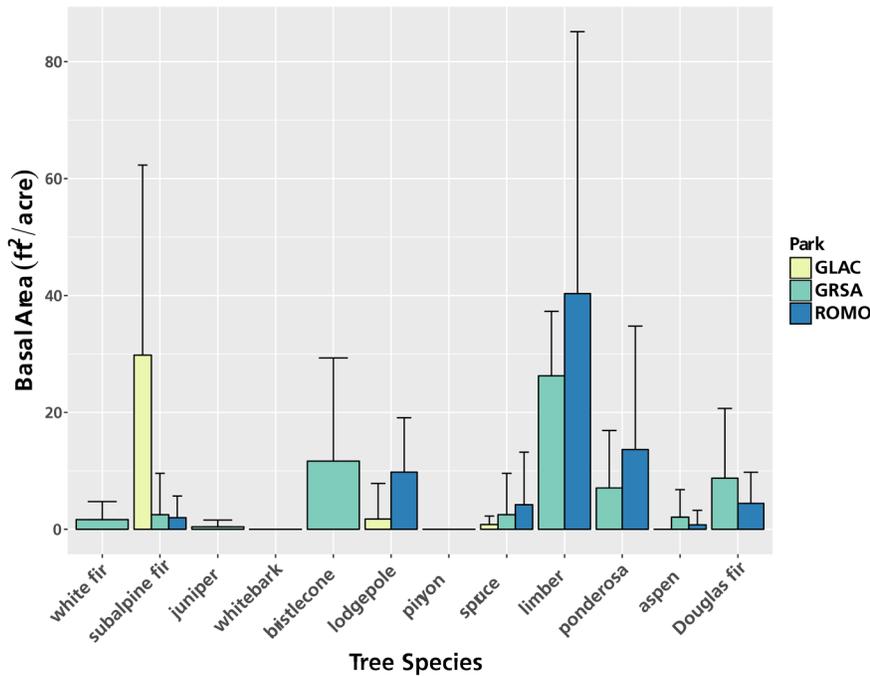


Figure 3. Mean basal area with standard deviation of each mature tree species found in stand composition subplots at Glacier National Park (GLAC; yellow), Great Sand Dunes National Park and Preserve (GRSA; green), and Rocky Mountain National Park (ROMO; blue) in 2013. Species include white fir (*Abies concolor*), subalpine fir (*Abies lasiocarpa*), Rocky Mountain juniper (*Juniperus scopulorum*), whitebark pine (*Pinus albicaulus*), bristlecone pine (*Pinus aristata*), lodgepole pine (*Pinus contorta*), piñon pine (*Pinus edulis*), Engelmann spruce (*Picea engelmannii*), limber pine (*Pinus flexilis*), ponderosa pine (*Pinus ponderosa*), quaking aspen (*Populus tremuloides*), and Douglas fir (*Pseudotsuga menziesii*).

## Conclusions

The funding for this work is no longer available but the ecological importance of whitebark, limber, and bristlecone pines in high-elevation woodlands and forest continues. Moreover, the stresses on these ecosystems are dynamic and may be increasing. Therefore, we recommend that parks, networks, and interested partners explore opportunities to continue monitoring five-needle pines. The frequency of monitoring would depend on funding and the magnitude of stressors on five-needle pine forests and the varying potential for rapid change in each park. It could be as often as every 5 years.

There are also opportunities to collaborate in analysis of these and other five-needle pine data. Because methods used

here are similar to those used by the USFS and the Greater Yellowstone Network, datasets spanning the Rocky Mountains could potentially be combined and analyses expanded to potentially reveal larger scale patterns or trends. To facilitate such an endeavor, the Rocky Mountain Network funded the creation of the Five-Needle Pine Monitoring Database. This relational database currently houses Rocky Mountain Network data, USFS data from the Rocky Mountains spanning Montana, Wyoming, and Colorado, and data collected by other partner organizations over the last 13 years (Borgman and Burns 2016). If future data are integrated into the database, we can explore broader-scale trends.

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NPS 117/139527, 140/139527, 121/139527, August 2017

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