



Upper Columbia Basin Network Limber Pine Community Dynamics 2013 Annual Monitoring Report

Craters of the Moon National Monument and Preserve

Natural Resource Data Series NPS/UCBN/NRDS—2013/583



ON THE COVER

Limber pine (*Pinus flexilis*) on cinder cone, Craters of the Moon National Monument and Preserve, Idaho.
Photograph by Devin Stucki

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Executive Summary

Limber pine (*Pinus flexilis*) at Craters of the Moon National Monument and Preserve (CRMO) is one of 14 vital signs identified in the long-term monitoring plan for the Upper Columbia Basin Network (UCBN). Vital signs are indicators of ecosystem health which represent a broad suite of ecological phenomena operating across multiple temporal and spatial scales. Vital signs were selected to meet the needs of park management and also to detect responses to unanticipated environmental conditions and management issues in the future. Limber pine is one of several white pine species susceptible to the invasive pathogen white pine blister rust (*Cronartium ribicola*) which has decimated stands throughout the Intermountain West and portions of the Pacific West Region. Limber pine trees are vulnerable to invasive pathogens as well as other stressors including native pathogens and climate-change induced drought and have been recognized as a high priority vital sign for CRMO. Although pathogen and insect infestations at CRMO are currently not high, declining trends observed in some white pine populations in the Cascade and Rocky Mountain ranges, coupled with the identification of incipient blister rust in CRMO by park staff in 2006, is cause for significant concern about the future status of these valuable communities. Monitoring limber pine community dynamics will allow CRMO to detect changes in the ecological condition of this community and perhaps to initiate more effective management intervention. Monitoring information from this project will also contribute meaningfully to the broader regional assessment of the status and trend of white pine species across western North America. Limber pine monitoring in CRMO is being closely coordinated with high-elevation whitebark pine (*Pinus albicaulis*) and foxtail pine (*Pinus balfouriana*) monitoring in the Klamath and Sierra Nevada Networks, which includes the use of a common protocol (McKinney et al. 2012). The data collected from this monitoring program will be used to quantify limber pine forest dynamics as identified in the monitoring objectives, i.e., species composition and structure, birth, death and growth rates, cone production, and the incidence of infection and infection severity by white pine blister rust, pine beetles, and dwarf mistletoe.

Protocol implementation began at CRMO with the installation of the first of three rotating panels, each consisting of a random sample of 30 permanent 50 x 50 m (2500 m²) plots, in June-July, 2011. Two additional oversample plots were also established and surveyed in 2011. These plots were resurveyed and incorporated into panel 2 during the 2012 field season for a total of 30 plots in 2012 (28 newly established, 2 resampled) and a total of 60 plots from 2011 and 2012. In 2013, 33 plots were established and sampled. The three extra plots were established because of a mid-season land access issue that resulted in a portion of our sampling frame becoming inaccessible, necessitating that seven plots be temporarily set aside until future sampling (see Discussion). In 2013, no incidences of white pine blister rust were found within the 33 sampled plots, although there is an active blister rust infection in a small stand of limber pine trees in the north end of the monument. Mountain pine beetle attacks were found in 0.4% of live *P. flexilis* trees ($n=2$) though evidence of mountain pine beetle attacks were found in 4 recently dead *P. flexilis* trees. Dwarf mistletoe was found in approximately 50% of live limber pine trees. The average number of limber pine trees per plot was 14 with a maximum of 57 trees. Seventy-three percent of live limber pine trees ($n=343$) had produced female cones. These results provide important baseline descriptions of CRMO's unique limber pine population, which occurs on the lower elevation periphery of the species' range.

Acknowledgments

Funding for this project was provided through the National Park Service Natural Resource Challenge and the Inventory and Monitoring Program. We thank the Craters of the Moon park superintendent and resource staff who met with us to discuss park management objectives and information needs, and who provided valuable logistical support to field operations. The park also provided the UCBN I&M team with field technicians to support data collection.

Background and Objectives

Many western North American coniferous forests are currently facing unprecedented health challenges, including upsurges of native pests and pathogens, invasive exotic species, and altered disturbance regimes. Increased atmospheric warming, carbon dioxide concentration, and nitrogen deposition, as well as changes in precipitation patterns (i.e., timing, magnitude, and type) pose additional short- and long-term threats. Each factor alone can alter forest ecosystem structure, function, and species composition, while additive or synergistic effects are possible if multiple agents act jointly. How forest ecosystems will respond to modern perturbations is uncertain, however the magnitude of change in structure and composition, and key ecological processes will likely be exceptional. Indeed, increased tree mortality rates over the last several decades have recently been documented across a broad range of latitude and forest types in western North America (van Mantgem et al. 2009).

Five-needle white pines (Family Pinaceae, Genus *Pinus*, Subgenus *Strobus*), and in particular whitebark pine, limber pine, and foxtail pine, are foundational species (Tomback and Achuff 2010) in upper subalpine and treeline forests of several National Park Service (NPS) Pacific West Region (PWR) parks, including Craters of the Moon National Monument and Preserve (CRMO). Ongoing declines of many foundation tree species pose an especially compelling problem because these species provide fundamental structure to a system and are thereby irreplaceable (Ellison et al. 2005). Foundation species generally occupy low trophic levels, create locally stable conditions required by many other species, and stabilize fundamental ecosystem processes (Ellison et al. 2005). In temperate zone forests (e.g., western North America) there often are only one or two foundational tree species, and therefore little functional redundancy is present in the system. If a foundation tree species is lost from these systems, it will likely lead to a cascade of secondary losses, shifts in biological diversity, and ultimately affect the functioning and stability of the community (Ebenman and Jonsson 2005).

Limber pine (*Pinus flexilis* James) occurs in areas throughout the Rocky Mountains, including parks within the UCBN, and extends to the east side of the Sierra Nevada (Figure 1). The species occupies a wide elevation range, and therefore occurs in lower elevation sites as well as upper subalpine and treeline habitats. By virtue of its status as a dominant component of forest stands, limber pine can have a large influence on key ecosystem processes and community dynamics, such as influencing snowmelt and stream flow, allowing for establishment of shade-tolerant plants, and providing habitat and food resources for birds and mammals. Limber pine is a pioneer of severe sites, moderating local environments and facilitating the establishment of other species (Baumeister and Callaway 2006). Limber pine cones open when seeds are ripe; some seeds remain within cones, while others fall to the ground. The seeds of limber pine are large, have rudimentary wings, and are prized by numerous birds and mammals. Its seeds are dispersed by Clark's nutcrackers and small mammals (Vander Wall 1988, Tomback et al. 2005).

Limber pine forms monotypic woodlands in much of the northern, highest-elevation portions of CRMO, and also occurs with Rocky Mountain juniper (*Juniperus scopulorum*) and Douglas fir (*Pseudotsuga menziesii*) in some areas of the park. Limber pine contributes significantly to the

biodiversity of CRMO, and is an integral part of the park's striking landscape. The presence of limber pine woodlands in CRMO dramatically contributes to visitor experience in addition to its important ecological significance. Despite the broad physiological tolerance exhibited by limber pine to harsh environmental conditions, the CRMO limber pine population is clearly unique in that it is growing at the very limits of its physiological tolerance and therefore provides an important opportunity for ecological learning. There is no history of formal inventory and monitoring of the CRMO limber pine population. During the 1960's, park policy included removal and girdling of pines infected with dwarf mistletoe in the vicinity of the park visitor center and along the park loop road which penetrates the northern portion of the lava flows. Beginning in 2006, CRMO initiated informal surveys of limber pine stands for early detection of white pine blister rust infection. There has been a hope that the aridity of the park will slow or prevent blister rust infection, but in 2006, three infected trees with active cankers were found and removed. Subsequent surveys have confirmed a small but well-established infection in several trees in the same stand. During 2011 pre-season field training, we photographed active cankers in limber pine trees in this stand. Park management removed two infected trees from the area in 2012 and an additional infected tree in 2013.

In 2009, we initiated a small pilot survey of six limber pine stands in CRMO following the Interagency Whitebark Pine Monitoring Protocol for the Greater Yellowstone Ecosystem (Greater Yellowstone Whitebark Pine Monitoring Working Group [hereafter referred to as GYWPMWG] 2007). No blister rust was found during that survey, although mountain pine beetle galleries were found in several trees, and dwarf mistletoe was ubiquitous. In 2010 we tested a draft version of the protocol currently being used by the Upper Columbia Basin Network (UCBN), as well as the Klamath Network (KLMN) and Sierra Nevada Network (SIEN; McKinney et al. 2012). We implemented the published protocol formally in 2011. This report describes the findings from the third and final "panel" of plots. Each panel consists of 30 permanent plots. Panel 1 was established in 2011 and reported by Stucki and Rodhouse (2012a). Panel 2 was established in 2012 and reported by Stucki and Rodhouse (2012b).

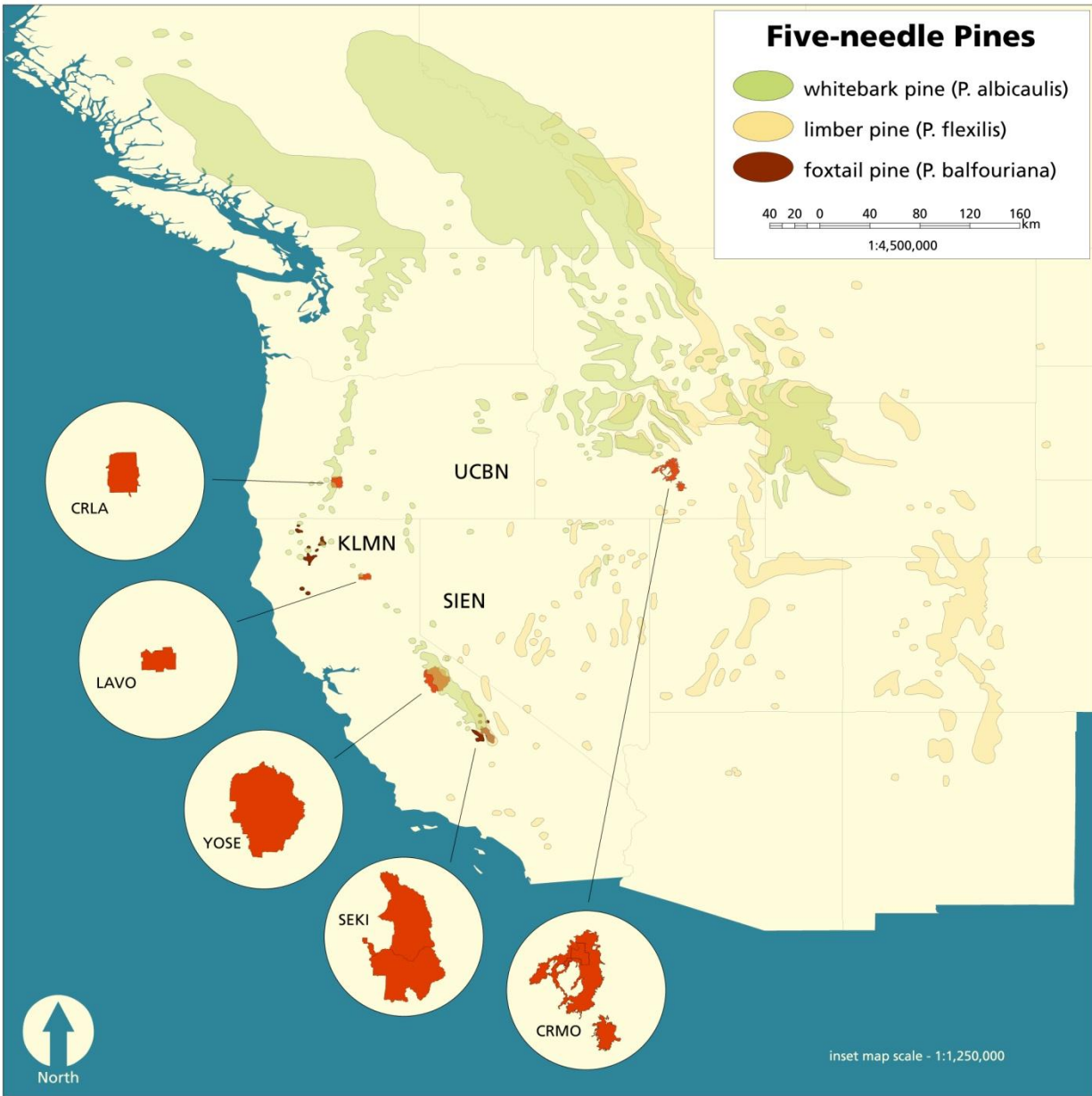


Figure 1. Distribution of whitebark pine, limber pine, and foxtail pine (from Little 1971) and locations of three Pacific West Region networks and associated parks.

Objectives

Limber pine monitoring objectives were established by ecologists from KLMN, SIEN, and the UCBN as part of a collaborative white pine monitoring protocol (McKinney et al. 2012). The objectives were also linked to the vital signs that were developed by each network and documented in network monitoring plans (Garrett et al. 2007, Sarr et al. 2007, Mutch et al. 2008). The anticipated impacts of blister rust, dwarf mistletoe, mountain pine beetle, and climate change to high-elevation pines based on published scientific literature and expert opinion were driving factors as well. Through an approach which involves monitoring individual trees within permanent plots, there will

be an ability to estimate key demographic parameters within white pine forest types. Our objectives are to detect status and trend in:

1. Trees species composition and structure
2. Tree species birth, death, and grow rates
3. Incidence of white pine blister rust (*Cronartium ribicola*) and level of crown kill
4. Incidence of pine beetle (*Dendroctonus spp.*) and severity of tree damage
5. Incidence of dwarf mistletoe (*Arceuthobium spp.*) and severity of tree damage
6. Cone production of white pine species

Methods

This section provides a detailed summary of the methods used for limber pine monitoring in CRMO. For the complete methodology of limber pine monitoring refer to the collaborative white pine monitoring protocol for networks in the Pacific West Region (McKinney et al. 2012).

Sampling Frame

Limber pine monitoring plots have been established within portions of two of the three limber pine plant associations mapped at CRMO (Bell et al. 2009): *P. flexilis*/*Purshia tridentata* Woodland, and *P. flexilis*/*Artemisia* spp. Woodland. A third sparsely vegetated and largely inaccessible association found across the interior of the lava flow, *P. flexilis*/*Chamaebatiaria millefolium*/*Poa secunda* Sparse Vegetation (Belle et al. 2009), was excluded from the sampling frame (McKinney et al. 2012). The *P. flexilis*/*Purshia tridentata* Woodland association is endemic to the Snake River Plain in Idaho and has been identified as critically imperiled by NatureServe (G1 ranking; Bell et al. 2009). The sampling frame includes all of these two *P. flexilis* woodland associations that occur within 2 km of a road and trail, excluding excessively steep areas with > 35 degrees slope and also excluding the southern portion of the Wilderness Trail which extends beyond the 2 km buffer from the southern portion of CRMO's loop road (Figure 2). The 2 km buffer was chosen to reduce crew exposure to unsafe travel across lava flows and potential accident response time, to reduce overall crew travel costs, and to ensure that sample sizes could be achieved each season. Although constrained, this sampling frame still encompasses 1,260 ha (20%) of the woodland associations in CRMO, capturing a substantial and representative proportion of *P. flexilis* woodlands within the park. The landscape at CRMO is relatively flat but there is a significant elevation gradient from south to north. The sampling frame contains a substantial portion of this gradient with elevations ranging from 1605-1900 m and Figure 3 shows a histogram of the elevations captured by the sample of plot locations. Elevation is a proxy for the effects of temperature and precipitation (Körner 2007), and sampling along the elevational gradient will enable hypotheses about the effects of climate on limber pine demography and rust infection dynamics to be addressed. Furthermore, the elevation gradient represented by the sample closely matches the one also captured by the UCBN's pika monitoring protocol in CRMO (Jeffress et al. 2011), facilitating integrated assessment of climate change impacts on these two climate-sensitive sentinel populations in the future.

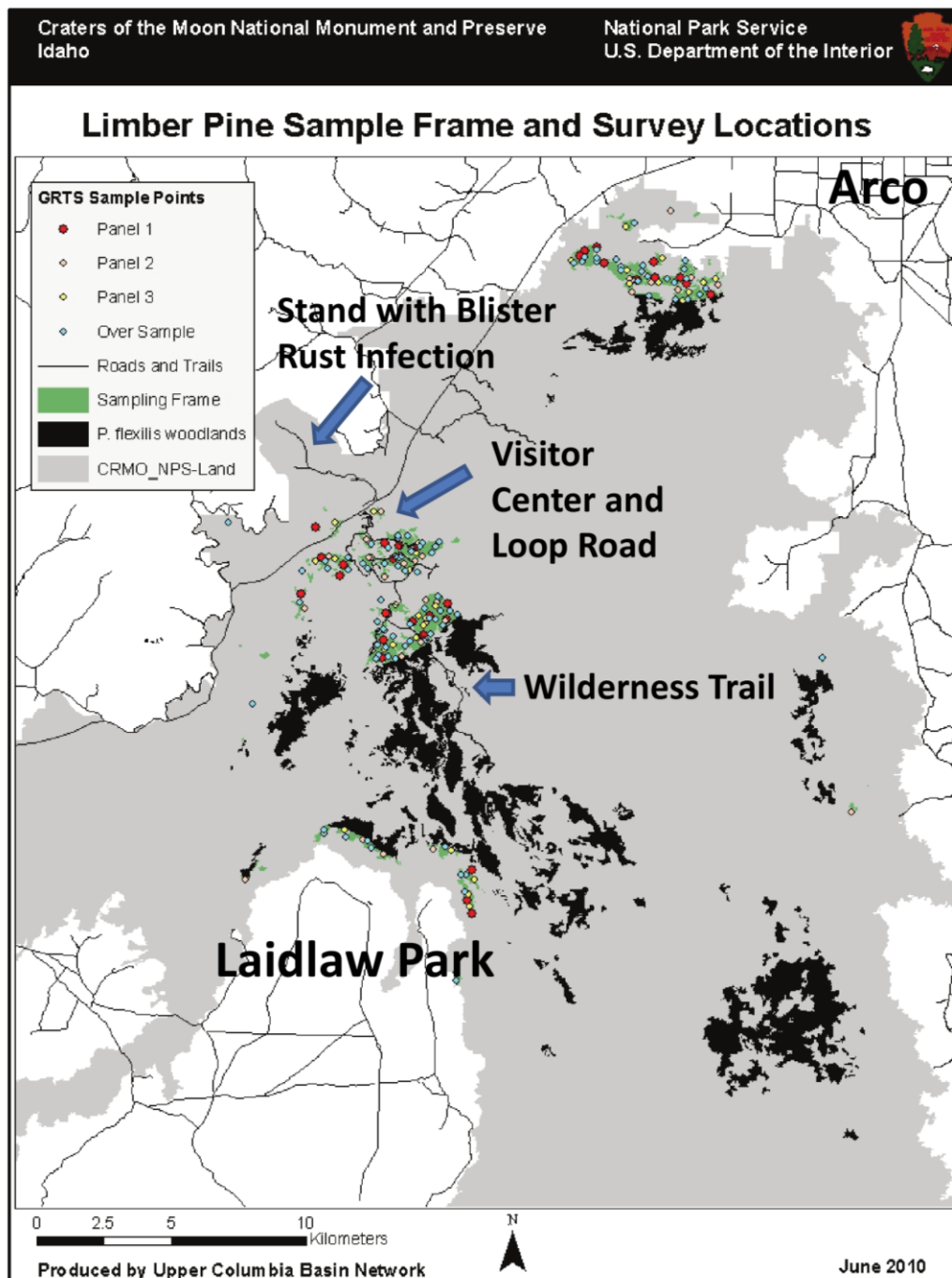


Figure 2. Limber pine monitoring sampling frame and GRTS sample of plot point locations within Craters of the Moon National Monument and Preserve. The sample frame (green) includes all areas of the park within 2 km of roads and trails that have been mapped by Bell et al. (2009) as *P. flexilis* woodland. Sample locations are separated into three equal panels of 30 points each of which will be visited once every three years in a rotating panel sampling design. An oversample of points was also drawn using the GRTS algorithm to support any eventual site additions, deletions, or replacements.

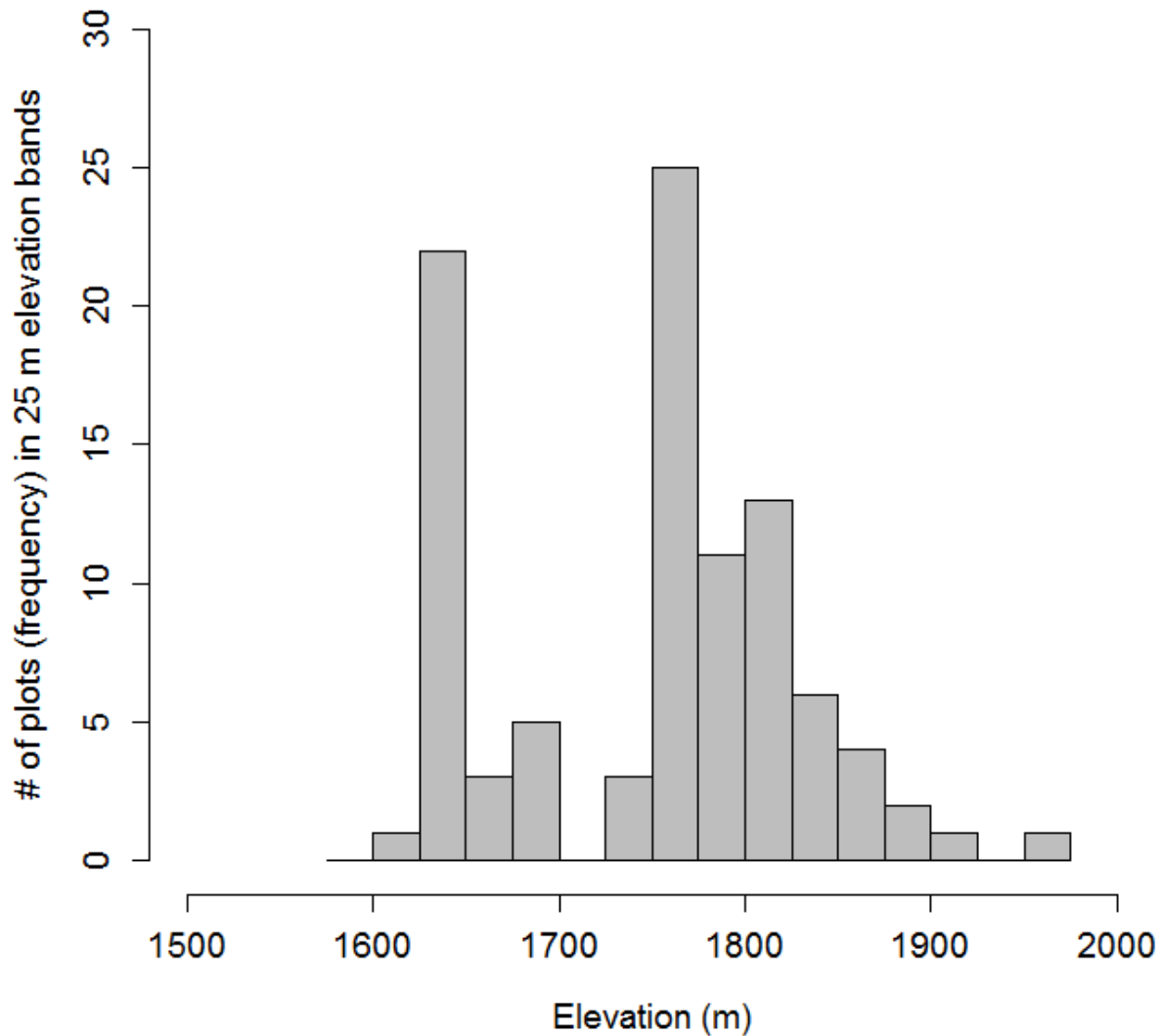


Figure 3. Histogram of elevations represented in the 93 installed plots for monitoring limber pine community dynamics in Craters of the Moon National Monument and Preserve.

The sites to be sampled have been identified using a randomized spatially-balanced sampling design via the Generalized Random Tessellation Stratified (GRTS) algorithm (Stevens and Olsen 2004). This design assigns permanent plots to random locations within the sampling frame while keeping the order of plots sampled unstructured and of equal-probability, as well as spatially balanced. This method allows for the addition of new sites or replacement sites which is useful in eliminating sampling difficulties that arise from site inaccessibility or sampling frame errors where, for instance, an unsuitable habitat type was erroneously mapped as suitable.

Frequency and Timing of Sampling

We have adopted a three-year rotating panel design for re-surveying permanent plots in CRMO. The sample of 90 plots in CRMO has been subdivided into three panels, each revisited once per three-year rotation cycle (a [1-2³] design, *sensu* MacDonald 2003; Table 1). Appendix A lists all 180 plot locations, including oversamples, drawn from the GRTS sample. The current status of each plot is also provided in the appendix. In 2013 all plots were sampled between July 14 and August 16.

Table 1. Revisit design for monitoring limber pine in the Upper Columbia Basin Network. Each panel consists of 30 plots. Panels are visited once per 3-year rotation, yielding a total sample size of 90 plots.

Panel	Year												
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
1 (n = 30)	x			x			x			x			x
2 (n = 30)		x			x			x			x		
3 (n = 30)			x			x			x			x	

Plot Layout

Macroplots, consisting of five adjacent 10 × 50 m subplots, and containing nine seedling/sapling regeneration plots (Figure 4) are used to measure and track forest demographic parameters, disease and insect occurrence, and magnitude of their impact. The response design for this protocol is compatible with the *Interagency Whitebark Pine Monitoring Protocol for the Greater Yellowstone Ecosystem* (GYWPMWG 2007) but differs in some respects, most notably, plot size. The 10 × 50 m plot size from the Yellowstone protocol has been increased to accommodate the often sparse distribution of white pines in our PWR parks and to adequately address forest demographic objectives. The UCBN uses a 50 × 50 m plot (0.25 ha or 2,500 m²) following analyses of pilot data collected in network parks in 2009–2010 (Figure 4; McKinney et al. 2012). This design effectively represents five parallel 10 × 50 m plots as used in the GRYN and as proposed by the Whitebark Pine Ecosystem Foundation (Tomback et al. 2005).

A total of nine square regeneration plots (3 × 3 m) are established within each 50 × 50 m macroplot to measure seedling regeneration (Figure 4). Regeneration subplots are located near each corner (4), at each midpoint between corners (4), and in the middle (1) of the macroplot (Figure 4). The current design was chosen because it provides a reasonable balance among sampling time constraints, observer accuracy and precision and total area sampled.

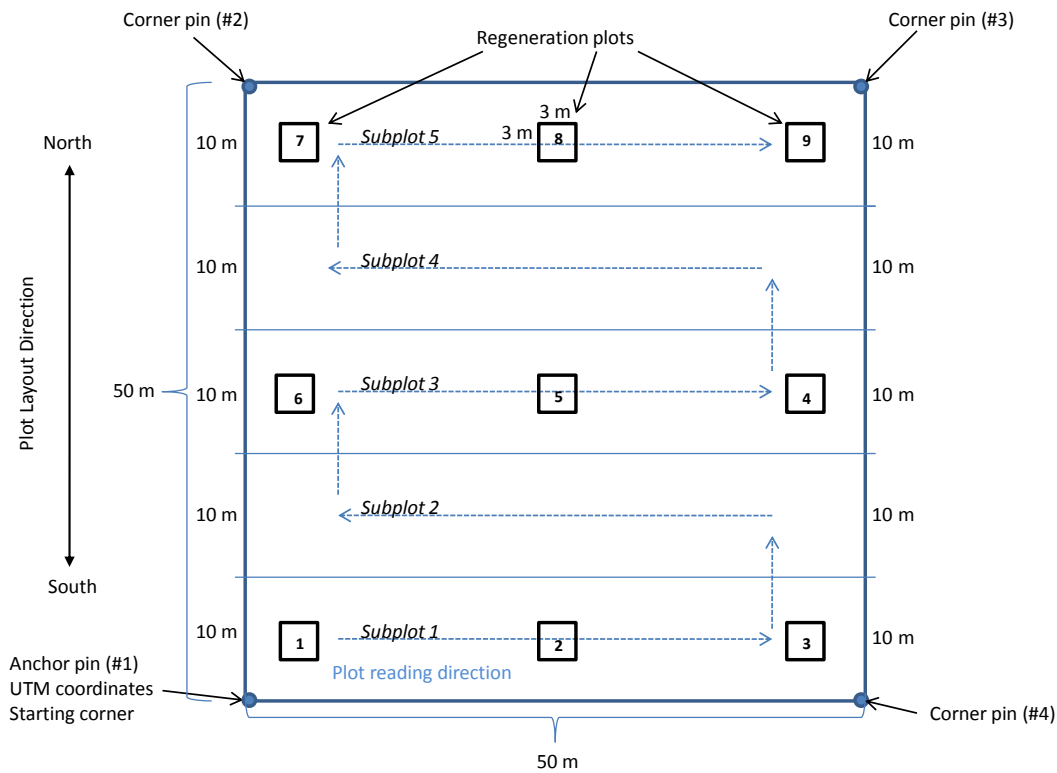


Figure 4. 50 × 50 m macroplot plot with five 10 × 50 m subplots, and nine 3 × 3 m regeneration plots used in UCBN and SIEN white pine monitoring.

Plot Measurements

Table 2 outlines the relationship among the variables, raw data, summarized data, and monitoring objectives. Detailed instructions on response design measurements are provided by McKinney et al. (2012) and only a general overview is presented here.

Each live tree taller than 1.37 m has a uniquely numbered metal tag attached to it, its species identified, and diameter at 1.37 m (breast height, dbh) and height measured. Dead trees are tagged and are distinguished between recently dead and dead. Recently dead trees have red needles present (but no green needles) and dead trees have no needles present. White pine blister rust infection is assessed for all living white pine trees. The bole and branches of white pine trees are each vertically divided into thirds (upper, middle, and bottom) and each third is assigned one of three rust condition classes: 1) absent—no sign of rust infection, 2) active cankers (aeciospores present), or 3) no active cankers, but with the presence of three of the following five indicators of infection: rodent chewing, flagging, swelling, roughened bark, and oozing sap. Mountain pine beetle occurrence is recorded for all pine trees using three indicators of beetle activity: pitch tubes, frass, and J-shaped galleries. The presence of galleries is only determined for recently dead and dead trees because bark has to be removed for this assessment. Dwarf mistletoe infection is recorded for all living white pine trees by

noting presence or absence for each tree. Cone production is recorded as to whether female cones are present or absent on each white pine tree. Live seedlings are tallied by species and height class in regeneration plots. Height classes are 1) 20 to <50 cm; 2) 50 to <100 cm; and 3) 100 to <137 cm.

Table 2. Relationship among variables, data, and objectives, from McKinney et al. (2012).

Variable	Raw Data	Summarized Data	Objectives Addressed
Species	Tree (nominal)	Trees per hectare (TPH); all spp., each spp., proportion of total by spp.	1. composition & structure
Diameter	Tree (cm)	Basal area (m ² /ha); all spp., each spp., proportion of total by spp. Mean diameter (cm) by spp. Diameter classes (5 cm); proportion and TPH by spp.	1. composition & structure 2. growth rate
Height	Tree (m)	Mean ht. (m); all spp. and by each spp. Height classes (3 m); proportion and TPH by spp.	1. composition & structure 2. growth rate
Status	Tree (live or dead)	Proportion live and dead; all spp and by each sp. TPH and proportion by 5 cm diameter classes in each condition; all spp and by each sp.	2. birth and death rates
Crown kill	Each of three parts of a tree (%)	Mean (%); individual trees, each sp, and all spp.	3. level of crown kill
Active canker	Each of three parts of a tree (p/a)	Proportion and TPH with active cankers by each white pine sp.	3. rust infection incidence
Inactive canker	Each of three parts of a tree (p/a)	Proportion and TPH with inactive cankers by each white pine sp.	3. rust infection incidence
Rust infection	Tree (p/a of active or inactive canker)	Proportion and TPH infected and healthy by each white pine sp. TPH by 5 cm diameter classes in each condition by each white pine sp.	3. rust infection incidence
Pine beetle	Tree (p/a)	Proportion and TPH with beetle sign; all spp and each sp.	4. incidence of pine beetle
Dwarf mistletoe	Tree (p/a)	Proportion and TPH with mistletoe sign; all spp and each sp.	5. incidence of dwarf mistletoe
Female cones	Tree (p/a)	Proportion and TPH with cones by each white pine sp.	6. cone production
Seedlings	9 m ² plot; number of each of three size classes by species	Mean (number per m ²); all spp and each sp for each size class.	1. composition & structure 2. birth rates

Results and Discussion

In 2013 we installed and sampled 33 plots in Craters of the Moon (Appendix A). A road that had been used in the past to access the area of the sampling frame near Arco, Idaho was closed to us in 2013, resulting in 7 plots being dropped from Panel 3. Three of these plots had already been established and sampled prior to loss of access while 4 other plots in the area remain unvisited. We sampled 7 oversample plots in the park to make up for those plots that were dropped. This report has been compiled using the data from all 33 plots that were established in 2013.

These 33 plots contained a total of 472 live limber pine trees, 42 dead limber pine trees, 7 live Rocky Mountain juniper trees, and one live Douglas fir (*Pseudotsuga menziesii*) tree. No limber pine trees were found with signs of blister rust infection in plots. Two live limber pine trees showed signs of attack by pine beetles (pitch tubes), and 4 recently dead limber pine tree showed signs of mountain pine beetle including pitch tubes and J-shaped galleries under the bark. Almost 50% ($n=235$) of live limber pine trees in plots were infected with dwarf mistletoe. In general, limber pine stands in this arid lava landscape are rather sparsely populated. The average number of live limber pine trees per 2500 m² plot was approximately 14, with a maximum of 57 live trees in a plot. About 73% ($n=472$) of live *P. flexilis* trees produced female cones. Additional summary statistics are reported in Table 3. Figure 5 shows live *P. flexilis* basal area per plot (m²/plot) and the number of live *P. flexilis* infected with mistletoe along the elevational gradient captured by the 2013 survey. There appears to be a positive relationship between elevation and basal area within the 2013 plots. A similar positive relationship between elevation and mistletoe infection may also be present.

A third year of field experience and these baseline results indicate that the monitoring effort is moving in a positive direction with a protocol well suited for this park. Conversations in 2011 with US Forest Service forest pathologists familiar with the CRMO limber pine population as well as limber pine populations in the Pioneer Mountains north of CRMO have underscored the importance of this monitoring effort to the broader scientific community-at-large (Jim Hoffman and Carl Jorgensen, US Forest Service, personal communication). Furthermore, in July 2013 prior to the start of the field season, UCBN staff joined colleagues from KLMN and SIEN in a meeting at Crater Lake National Park (CRLA) to review the protocol and clarify outstanding methodological questions. All participants expressed satisfaction with the protocol, progress in the implementation of the program in their respective parks, and eagerness to continue to collaborate.

The CRMO population occurs at the lower elevation periphery of the species' physiological tolerance in Idaho, and therefore studying the dynamics of this population over time can inform questions about how the species may respond to drought and other climatic events that are expected to become more frequent and intense under projected climate change. This information will also be integral for management strategies concerned with these issues in the future. The results from 2011 through 2013 underscore several unique characteristics of the population. The sparse distribution of limber pine in stands is striking, as is the high levels of mistletoe infection. The endemic but low-level infestation of mountain pine beetle in the population is also noteworthy. These characteristics are apparently quite different from limber pine populations growing at higher elevations in the mountains of central

Idaho, which are reported to have higher rates of blister rust infection and lower rates of mistletoe infestation (Jim Hoffman, US Forest Service, personal communication). Long-term monitoring will be important to provide a more comprehensive understanding of the population and to provide early detection of significant changes and trends that may require management intervention.

Table 3. Summary table of 2011-2013 results for CRMO limber pine monitoring.

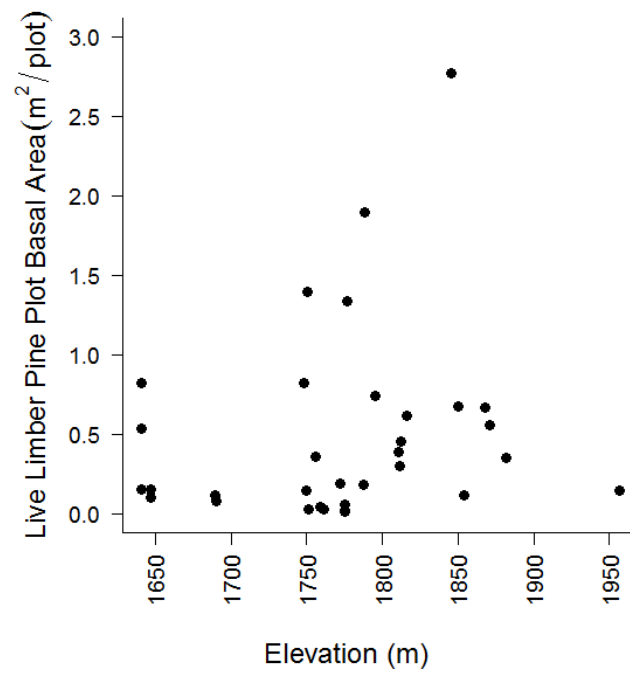
Metric	2011 Status ¹	2012 Status ²	2013 Status ³
Number of established plots	32 (na)	30 (na)	33 (na)
Average live <i>Juniperus scopulorum</i> basal area (m ² /ha)	0.13 (0.87)	0.606 (0.308)	0.190 (0.056)
Average live <i>Pinus flexilis</i> basal area (m ² /ha)	1.39 (1.50)	1.699 (1.639)	1.970 (2.418)
Average live <i>Pseudotsuga menziesii</i> basal area (m ² /ha)	0.70 (0.00)	0.000 (0.000)	0.018 (0.000)
Average number of <i>J. scopulorum</i> trees/ha	4.88	3.60 (11.43)	0.848 (4.214)
Average number of <i>P. flexilis</i> trees/ha	51.63 (63.03)	74.67 (95.31)	57.21 (59.09)
Average number of <i>P. menziesii</i> trees/ha	7.25	0.00 (0.00)	4 (0.00)
Blister Rust Infection Rate (%)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Dwarf Mistletoe Infection Rate (%)	26.15 (0.60)	32.68 (0.47)	49.79 (0.50)
Mountain Pine Beetle Infection Rate (%)	0.00 (0.00)	0.00 (0.00)	0.004 (0.065)
Average regeneration of <i>J. scopulorum</i> 20-50cm (seedlings/m ² /macroplot)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Average regeneration of <i>J. scopulorum</i> 50-100cm (seedlings/m ² /macroplot)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Average regeneration of <i>J. scopulorum</i> 100-137cm (seedlings/m ² /macroplot)	0.001 (0.004)	0.000 (0.000)	0.000 (0.000)
Average regeneration of <i>P. flexilis</i> 20-50cm (seedlings/m ² /macroplot)	0.004 (0.009)	0.002 (0.005)	0.007 (0.207)
Average regeneration of <i>P. flexilis</i> 50-100cm (seedlings/m ² /macroplot)	0.004 (0.014)	0.002 (0.005)	0.003 (0.115)
Average regeneration of <i>P. flexilis</i> 100-137cm (seedlings/m ² /macroplot)	0.000 (0.000)	0.001 (0.004)	0.000 (0.000)
Average regeneration of <i>P. menziesii</i> 20-50cm (seedlings/m ² /macroplot)	0.002	0.000 (0.000)	0.000 (0.000)
Average regeneration of <i>P. menziesii</i> 50-100cm (seedlings/m ² /macroplot)	0.003	0.000 (0.000)	0.000 (0.000)
Average regeneration of <i>P. menziesii</i> 100-137cm (seedlings/m ² /macroplot)	0.000	0.000 (0.000)	0.000 (0.000)
Limber pine trees with female cones (%)	71.67 (0.01)	62.68 (0.49)	72.67 (0.45)

¹Only 8 plots in 2011 with *J. scopulorum* (n=8) and 1 plot in 2011 with *P. menziesii* (n=1). Two extra oversample plots established in 2011 were subsumed into panel 2

²Only 3 plots in 2012 with *J. scopulorum* (n=3) and no plots in 2012 with *P. menziesii* (n=0).

³Only 2 plots in 2013 with *J. scopulorum* (n=2) and 1 plot in 2013 with *P. menziesii* (n=1). Three extra plots established in 2013.

A)



B)

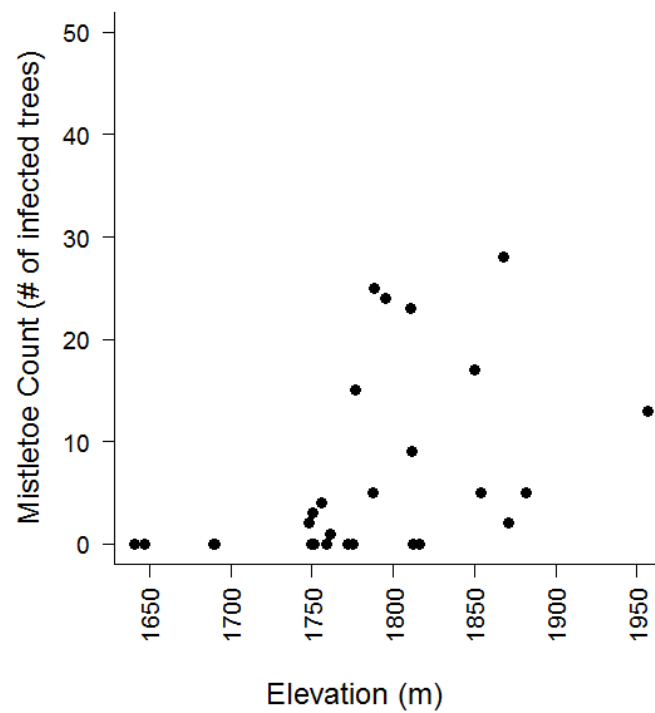


Figure 5. A) Live limber pine basal area (m²) per plot and B) count of trees infected with mistletoe along the elevational gradient captured in the 2013 survey.

Literature Cited

- Baumeister, D., and R. M. Callaway. 2006. Facilitation by *Pinus flexilis* during succession: A hierarchy of mechanisms benefits other plant species. *Ecology* 87:1816–1830.
- Bell, J., D. Cogan, J. J. Erixson, and J. Von Loh. 2009. Vegetation inventory project report: Craters of the Moon National Monument and Preserve. Natural Resource Technical Report NPS/UCBN/NRTR—2009/277. National Park Service, Fort Collins, Colorado.
- Ebenman, B., and T. Jonsson. 2005. Using community viability analysis to identify fragile systems and keystone species. *Trends in Ecology and Evolution* 20:568–575.
- Ellison, A. E., M. S. Bank, B. D. Clinton, E. A. Colburn, K. Elliott, C. R. Ford, D. R. Foster, B. D. Kloeppel, J. D. Knoepp, G. M. Lovett, J. Mohan, D. A. Orwig, N. L. Rodenhouse, W. V. Sobczak, K. A. Stinson, J. K. Stone, C. M. Swan, J. Thompson, B. Von Holle, and J. R. Webster. 2005. Loss of foundation species: consequences for the structure and dynamics of forested ecosystems. *Frontiers in Ecology and the Environment* 3:479–486.
- Garrett, L. K., T. J. Rodhouse, G. H. Dicus, C. C. Caudill, and M. R. Shardlow. 2007. Upper Columbia Basin Network vital signs monitoring plan. Natural Resource Report NPS/UCBN/NRR—2007/002. National Park Service, Fort Collins, Colorado.
- Greater Yellowstone Whitebark Pine Monitoring Working Group. 2007. Interagency whitebark pine monitoring protocol for the Greater Yellowstone Ecosystem, v 1.0. Greater Yellowstone Coordinating Committee, Bozeman, Montana. Unpublished.
- Jeffress, M. R., J. Apel, L. K. Garrett, G. Holm, D. Larson, N. Nordensten, and T. J. Rodhouse. 2011. Monitoring the American pika (*Ochotona princeps*) in the Pacific West Region - Crater Lake National Park, Craters of the Moon National Monument and Preserve, Lassen Volcanic National Park, and Lava Beds National Monument: Narrative Version 1.0. Natural Resource Report NPS/UCBN/NRR—2011/336. National Park Service, Fort Collins, Colorado.
- Körner, C. 2007. The use of ‘altitude’ in ecological research. *Trends in Ecology and Evolution* 22:569–574.
- Little, E. L., Jr. 1971. Conifers and important hardwoods. Volume 1 of Atlas of United States trees. U.S. Department of Agriculture Miscellaneous Publication 1146.
- McDonald, T. L. 2003. Review of environmental monitoring methods: Survey designs. *Environmental Monitoring and Assessment* 85:277–292.
- McKinney, S. T., T. Rodhouse, L. Chow, A. Chung-MacCoubrey, G. Dicus, L. Garrett, K. Irvine, S. Mohren, D. Odion, D. Sarr, and L. A. Starcevich. 2012. Monitoring white pine (*Pinus albicaulis*, *P. balfouriana*, *P. flexilis*) community dynamics in the Pacific West Region - Klamath, Sierra Nevada, and Upper Columbia Basin Networks: Narrative and 16 Standard Operating Procedures (bound separately) version 1.0. Natural Resource Report NPS/PWRO/NRR—2011/XXX. National Park Service, Fort Collins, Colorado.

- Mutch, L. S., M. G. Rose, A. M. Heard, R. R. Cook, and G. L. Entsminger. 2008. Sierra Nevada Network vital signs monitoring plan. Natural Resource Report NPS/ SIEN/NRR—2008/072. National Park Service, Fort Collins, Colorado.
- Sarr, D. A., D. C. Odion, S. R. Mohren, E. E. Perry, R. L. Hoffman, L. K. Bridy, and A. A. Merton. 2007. Vital signs monitoring plan for the Klamath Network: Phase III report. Natural Resource Technical Report NPS/KLMN/NRR—2007/016, National Park Service, Fort Collins, Colorado.
- Stevens, D. L., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. *Journal of the American Statistical Association* 99:262–278.
- Tomback, D. F., A. W. Schoettle, K. E. Chevalier, and C. A. Jones. 2005. Life on the Edge for limber pine: Seed dispersal within peripheral population. *Ecoscience* 12:519-529.
- Tomback, D. F., and P. Achuff. 2010. Blister rust and western forest biodiversity: ecology, values, and outlook for white pines. *Forest Pathology* 40:186-225.
- Vander Wall, S. B. 1988. Foraging of Clark's Nutcracker on rapidly changing pine seed resources. *Condor* 90:621-631.
- van Mantgem, P. J., N. L. Stephenson, J. C. Byrne, L. D. Daniels, J. F. Franklin, P. Z. Fulé, M. E. Harmon, A. J. Larson, J. M. Smith, A. H. Taylor, T. T. Veblen. 2009. Widespread increase of tree mortality rates in the western United States. *Science* 323:521–523.

Appendix A. Plots and oversamples evaluated and established for monitoring in 2011-2013 at Craters of the Moon National Monument and Preserve (CRMO).

Table A-1. Spatially-balanced list of sampling locations for CRMO, organized by panel. Panel 3 sites with access issues are identified in the Notes column. Oversample locations provide the replacements for sites dropped during office and field evaluation. Note that UTM X and UTM Y are the plot corner 1 coordinates as established in the field, and no longer match exactly the coordinates produced by the GRTS algorithm used to navigate to the plot during initial set-up.

Plot ID	UTM X	UTM Y	Original Panel	Status	Notes	Final Panel
Site-001	301108	4825065	Panel_1	Established		Panel_1
Site-002	300938	4824871	Panel_1	Established		Panel_1
Site-003	293580	4810610	Panel_1	Established		Panel_1
Site-004	293666	4814204	Panel_1	Established		Panel_1
Site-005	301828	4824600	Panel_1	Established		Panel_1
Site-006	295992	4811964	Panel_1	Established		Panel_1
Site-007	291987	4813011	Panel_1	Established		Panel_1
Site-008	294159	4814128	Panel_1	Established		Panel_1
Site-009	303667	4824640	Panel_1	Established		Panel_1
Site-010	294712	4811265	Panel_1	Dropped	No trees	None
Site-011	291291	4813692	Panel_1	Established		Panel_1
Site-012	296913	4800376	Panel_1	Established		Panel_1
Site-013	304659	4824050	Panel_1	Established		Panel_1
Site-014	293708	4811587	Panel_1	Established		Panel_1
Site-015	292100	4813409	Panel_1	Established		Panel_1
Site-016	296891	4801995	Panel_1	Established		Panel_1
Site-017	301605	4825253	Panel_1	Established		Panel_1
Site-018	305824	4823410	Panel_1	Dropped	No trees	None
Site-019	295115	4810759	Panel_1	Established		Panel_1
Site-020	294730	4814022	Panel_1	Established		Panel_1
Site-021	303039	4823964	Panel_1	Established		Panel_1
Site-022	295974	4811384	Panel_1	Established		Panel_1
Site-023	290552	4812330	Panel_1	Established		Panel_1
Site-024	293947	4813626	Panel_1	Established		Panel_1
Site-025	303719	4824073	Panel_1	Dropped	No trees	None
Site-026	295340	4811495	Panel_1	Dropped	No trees	None
Site-027	291079	4814801	Panel_1	Established		Panel_1
Site-028	296718	4800891	Panel_1	Established		Panel_1
Site-029	304915	4823823	Panel_1	Dropped	No trees	None
Site-030	293565	4809910	Panel_1	Established		Panel_1
Site-031	291577	4813730	Panel_2	Established		Panel_2
Site-032	295472	4802778	Panel_2	Dropped	No trees	None

Table A-1 (continued). Spatially-balanced list of sampling locations for CRMO, organized by panel. Panel 3 sites with access issues are identified in the Notes column. Oversample locations provide the replacements for sites dropped during office and field evaluation. Note that UTM X and UTM Y are the plot corner 1 coordinates as established in the field, and no longer match exactly the coordinates produced by the GRTS algorithm used to navigate to the plot during initial set-up.

Plot ID	UTM X	UTM Y	Original Panel	Status	Notes	Final Panel
Site-033	304300	4826526	Panel_2	Dropped	No trees	None
Site-034	306073	4823807	Panel_2	Dropped	No trees	None
Site-035	295200	4811218	Panel_2	Established		Panel_2
Site-036	294765	4813555	Panel_2	Established		Panel_2
Site-037	302870	4823978	Panel_2	Established		Panel_2
Site-038	295598	4812002	Panel_2	Dropped	No trees	None
Site-039	290663	4811750	Panel_2	Dropped	No trees	None
Site-040	294355	4813440	Panel_2	Established		Panel_2
Site-041	303580	4823866	Panel_2	Dropped	No trees	None
Site-042	295179	4812077	Panel_2	Established		Panel_2
Site-043	293163	4813665	Panel_2	Established		Panel_2
Site-044	288434	4801641	Panel_2	Established		Panel_2
Site-045	304577	4823629	Panel_2	Dropped	No trees	None
Site-046	294304	4809980	Panel_2	Dropped	Steep, unsafe	None
Site-047	292955	4814363	Panel_2	Established		Panel_2
Site-048	292834	4803155	Panel_2	Established		Panel_2
Site-049	302880	4823540	Panel_2	Dropped	No trees	None
Site_050	311063	4804198	Panel_2	Dropped	No trees	None
Site-051	295021	4810522	Panel_2	Established		Panel_2
Site-052	295060	4813705	Panel_2	Established		Panel_2
Site-053	302769	4824019	Panel_2	Established		Panel_2
Site-054	295907	4811324	Panel_2	Dropped	No trees	None
Site-055	293219	4810175	Panel_2	Established		Panel_2
Site-056	293538	4815390	Panel_2	Established		Panel_2
Site-057	305092	4824058	Panel_2	Dropped	No trees	None
Site-058	293668	4812967	Panel_2	Established		Panel_2
Site-059	293075	4813684	Panel_2	Established		Panel_2
Site-060	293628	4802601	Panel_2	Established		Panel_2
Site-061	300591	4824699	Panel_3	Established		Panel_3
Site-062	293978	4810413	Panel_3	Established		Panel_3
Site-063	294917	4814198	Panel_3	Established		Panel_3
Site-064	292151	4803504	Panel_3	Established		Panel_3
Site-065	304011	4824783	Panel_3	Dropped	No trees	None
Site-066	294908	4811493	Panel_3	Established		Panel_3
Site-067	291054	4813537	Panel_3	Established		Panel_3
Site-068	296790	4801111	Panel_3	Dropped	No trees	None

Table A-1 (continued). Spatially-balanced list of sampling locations for CRMO, organized by panel. Panel 3 sites with access issues are identified in the Notes column. Oversample locations provide the replacements for sites dropped during office and field evaluation. Note that UTM X and UTM Y are the plot corner 1 coordinates as established in the field, and no longer match exactly the coordinates produced by the GRTS algorithm used to navigate to the plot during initial set-up.

Plot ID	UTM X	UTM Y	Original Panel	Status	Notes	Final Panel
Site-069	304753	4823217	Panel_3	Established	Currently no access	Panel_3
Site-070	294080	4811914	Panel_3	Dropped	No trees	None
Site-071	291785	4813612	Panel_3	Established		Panel_3
Site-072	297015	4801669	Panel_3	Dropped	No trees	None
Site-073	302627	4825972	Panel_3	Dropped	No trees	None
Site-074	305535	4823870	Panel_3	Dropped	No trees	None
Site-075	295120	4811155	Panel_3	Established		Panel_3
Site-076	294809	4813860	Panel_3	Established		Panel_3
Site-077	303850	4823865	Panel_3	Not Established	Currently no access	Panel_3
Site-078	295168	4811396	Panel_3	Established		Panel_3
Site-079	293237	4815406	Panel_3	Established		Panel_3
Site-080	296835	4800639	Panel_3	Dropped	No trees	None
Site-081	305013	4823533	Panel_3	Dropped	No trees	None
Site-082	293649	4810222	Panel_3	Established		Panel_3
Site-083	291798	4814981	Panel_3	Established		Panel_3
Site-084	296125	4802713	Panel_3	Dropped	No trees	None
Site-085	302765	4823835	Panel_3	Not Established	Currently no access	Panel_3
Site-086	305987	4824004	Panel_3	Dropped	No trees	None
Site-087	294807	4810705	Panel_3	Established		Panel_3
Site-088	294619	4813224	Panel_3	Established		Panel_3
Site-089	302677	4824350	Panel_3	Not Established	Currently no access	Panel_3
Site-090	295536	4811872	Panel_3	Established		Panel_3
Site-091	293447	4810025	Oversample	Established	Replace site 10	Panel_1
Site-092	294173	4813653	Oversample	Established	Replace site 18	Panel_1
Site-093	304496	4823236	Oversample	Established	Replace site 25	Panel_1
Site-094	293645	4810962	Oversample	Established	Replace site 26	Panel_1
Site-095	295045	4814190	Oversample	Established	Replace site 29	Panel_1
Site-096	293003	4803076	Oversample	Established	Replace site 32	Panel_2
Site-097	301546	4824656	Oversample	Dropped	No trees	None
Site-098	287800	4814990	Oversample	Dropped	No trees	None
Site-099	295195	4810590	Oversample	Established	Replace site 33	Panel_2
Site-100	294978	4814063	Oversample	Established	Replace site 34	Panel_2
Site-101	302472	4824454	Oversample	Established	Replace site 38	Panel_2
Site-102	295745	4811671	Oversample	Dropped	No trees	None
Site-103	293382	4810413	Oversample	Established	Replace site 39	Panel_2
Site-104	295699	4814271	Oversample	Established	Replace site 41	Panel_2
Site-105	304899	4824020	Oversample	Dropped	No trees	None

Table A-1 (continued). Spatially-balanced list of sampling locations for CRMO, organized by panel. Panel 3 sites with access issues are identified in the Notes column. Oversample locations provide the replacements for sites dropped during office and field evaluation. Note that UTM X and UTM Y are the plot corner 1 coordinates as established in the field, and no longer match exactly the coordinates produced by the GRTS algorithm used to navigate to the plot during initial set-up.

Plot ID	UTM X	UTM Y	Original Panel	Status	Notes	Final Panel
Site-106	294427	4813153	Oversample	Established	Replace site 45	Panel_2
Site-107	292282	4813212	Oversample	Established	Replace site 46	Panel_2
Site-108	296658	4801826	Oversample	Dropped	No trees	None
Site-109	301554	4825113	Oversample	Established	Replace site 49	Panel_2
Site-110	305403	4823420	Oversample	Established	Replace site 50	Panel_2
Site-111	293677	4810342	Oversample	Established	Replace site 54	Panel_2
Site-112	294642	4814036	Oversample	Established	Replace site 57	Panel_2
Site-113	302275	4824725	Oversample	Not Established	Currently no access	Panel_3
Site-114	296363	4811541	Oversample	Established	Replace site 68	Panel_3
Site-115	293386	4811280	Oversample	Established	Replace site 70	Panel_3
Site-116	294287	4813701	Oversample	Established	Replace site 72	Panel_3
Site-117	304932	4823247	Oversample	Established	Currently no access	Panel_3
Site-118	293804	4809963	Oversample	Established	Replace site 74	Panel_3
Site-119	291520	4813280	Oversample	Established	Replace site 80	Panel_3
Site-120	295907	4802853	Oversample	Dropped	No trees	None
Site-121	302949	4826106	Oversample	Dropped	No trees	None
Site-122	305605	4823643	Oversample	Established	Currently no access	Panel_3
Site-123	295375	4810819	Oversample	Established	Replace site 84	Panel_3
Site-124	294664	4813915	Oversample	Established	Replace site 86	Panel_3
Site-125	303216	4824298	Oversample	Not Evaluated	Currently no access	Oversample
Site-126	295692	4812182	Oversample	Dropped	No trees	None
Site-127	290585	4813182	Oversample	Dropped	No trees	None
Site-128	294151	4813371	Oversample	Available		Panel_1
Site-129	303091	4823933	Oversample	Not Evaluated	Currently no access	Oversample
Site-130	309948	4809940	Oversample	Dropped	No trees	None
Site-131	294592	4810538	Oversample	Available		Panel_1
Site-132	295425	4813856	Oversample	Available		Panel_1
Site-133	302442	4824333	Oversample	Not Evaluated	Currently no access	Oversample
Site-134	295560	4811369	Oversample	Dropped	No trees	None
Site-135	293327	4809866	Oversample	Available		Panel_1
Site-136	293774	4814043	Oversample	Available		Panel_1
Site-137	304811	4824368	Oversample	Not Evaluated	Currently no access	Oversample
Site-138	294889	4813122	Oversample	Dropped	No trees	None
Site-139	293029	4813279	Oversample	Available		Panel_2
Site-140	288732	4808224	Oversample	Dropped	No trees	None
Site-141	304159	4824010	Oversample	Not Evaluated	Currently no access	Oversample
Site-142	295629	4812236	Oversample	Dropped	No trees	None

Table A-1 (continued). Spatially-balanced list of sampling locations for CRMO, organized by panel. Panel 3 sites with access issues are identified in the Notes column. Oversample locations provide the replacements for sites dropped during office and field evaluation. Note that UTM X and UTM Y are the plot corner 1 coordinates as established in the field, and no longer match exactly the coordinates produced by the GRTS algorithm used to navigate to the plot during initial set-up.

Plot ID	UTM X	UTM Y	Original Panel	Status	Notes	Final Panel
Site-143	293406	4810927	Oversample	Available		Panel_2
Site-144	295561	4814067	Oversample	Available		Panel_2
Site-145	304876	4824692	Oversample	Not Evaluated	Currently no access	Oversample
Site-146	293519	4812093	Oversample	Available		Panel_2
Site-147	292280	4813651	Oversample	Established		Panel_3
Site-148	296521	4801852	Oversample	Dropped	No trees	Oversample
Site-149	301092	4824809	Oversample	Established		Panel_3
Site-150	294440	4810351	Oversample	Established		Panel_3
Site-151	294148	4814375	Oversample	Established		Panel_3
Site-152	291404	4803376	Oversample	Established		Panel_3
Site-153	303254	4824527	Oversample	Not Evaluated	Currently no access	Oversample
Site-154	296106	4811673	Oversample	Dropped	No trees	None
Site-155	290472	4812002	Oversample	Dropped	No trees	None
Site-156	293635	4813441	Oversample	Established		Panel_3
Site-157	303463	4824107	Oversample	Not Evaluated	Currently no access	Oversample
Site-158	295338	4811425	Oversample	Dropped	No trees	None
Site-159	291444	4813532	Oversample	Established		Panel_3
Site-160	296634	4801212	Oversample	NotEvaluated		Oversample
Site-161	303513	4823379	Oversample	NotEvaluated		Oversample
Site-162	295125	4811768	Oversample	NotEvaluated		Oversample
Site-163	292853	4813451	Oversample	NotEvaluated		Oversample
Site-164	296295	4797898	Oversample	NotEvaluated		Oversample
Site-165	304473	4823877	Oversample	NotEvaluated		Oversample
Site-166	294056	4809875	Oversample	NotEvaluated		Oversample
Site-167	293170	4814174	Oversample	NotEvaluated		Oversample
Site-168	293147	4802810	Oversample	NotEvaluated		Oversample
Site-169	300702	4824615	Oversample	NotEvaluated		Oversample
Site-170	293599	4810996	Oversample	NotEvaluated		Oversample
Site-171	294501	4814468	Oversample	NotEvaluated		Oversample
Site-172	292226	4803247	Oversample	NotEvaluated		Oversample
Site-173	301546	4824790	Oversample	NotEvaluated		Oversample
Site-174	295805	4811144	Oversample	NotEvaluated		Oversample
Site-175	294623	4811194	Oversample	NotEvaluated		Oversample
Site-176	294080	4813699	Oversample	NotEvaluated		Oversample
Site-177	300998	4824669	Oversample	NotEvaluated		Oversample
Site-178	293957	4810738	Oversample	NotEvaluated		Oversample
Site-179	294140	4814465	Oversample	NotEvaluated		Oversample

Table A-1 (continued). Spatially-balanced list of sampling locations for CRMO, organized by panel. Panel 3 sites with access issues are identified in the Notes column. Oversample locations provide the replacements for sites dropped during office and field evaluation. Note that UTM X and UTM Y are the plot corner 1 coordinates as established in the field, and no longer match exactly the coordinates produced by the GRTS algorithm used to navigate to the plot during initial set-up.

Plot ID	UTM X	UTM Y	Original Panel	Status	Notes	Final Panel
Site-180	291407	4803515	Oversample	NotEvaluated		Oversample