



Upper Columbia Basin Network Limber Pine Community Dynamics 2012 Annual Monitoring Report

Craters of the Moon National Monument and Preserve

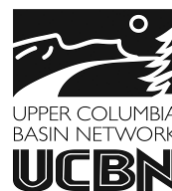
Natural Resource Data Series NPS/UCBN/NRDS—2012/382



ON THE COVER

Limber pine (*Pinus flexilis*) on lava flow, Craters of the Moon National Monument and Preserve, Idaho.
Photograph by: Devin Stucki, Upper Columbia Basin Network.

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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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. 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 in some populations observed in white pine populations in the Cascade and Rocky Mountain ranges, coupled with the identification of incipient blister rust and mountain pine beetle infestations in the park, 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, for a total of 32 plots, for use in comparison of accuracy of response variable measurements between years (see discussion and Appendix 3). These plots were resurveyed and incorporated into panel 2 during the 2012 field season for a total of 30 plots (28 newly established, 2 resampled). A grand total of 60 plots have been established at the end of the 2012 field season with the final 30 plots scheduled for 2013. In 2012, no incidences of white pine blister rust or mountain pine beetle attacks were found within the 30 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. Dwarf mistletoe was found in 33% of the live limber pine trees. There were no active signs of mountain pine beetle infestation, although park staff report an increasing frequency of beetle-killed limber pine trees scattered throughout the northern portion of the monument. The average number of limber pine trees per plot was 19 with a maximum of 106 trees. Sixty-three percent of live limber pine trees ($n=351$) 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 Servicewide 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 in 2012. In 2012 the park also provided the UCBN I&M team with two technicians to round out the field crew, and this was greatly appreciated and made for a very efficient and successful field season.

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, moderating local environments 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*) 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.

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). In 2011 we implemented the first full panel of 30 plots, plus two oversamples, following approval of the McKinney et al. (2012) protocol. Results from 2011 are reported in Stucki and Rodhouse (2012). This report presents the results for the second full panel of 30 plots established and surveyed in August 2012. Note that panel 2 includes the two oversample plots that were established in 2011. This is the second formal year of protocol implementation, and the permanent plots established in 2012 represent the second of 3 "panels" of plots that will be monitored into the future.

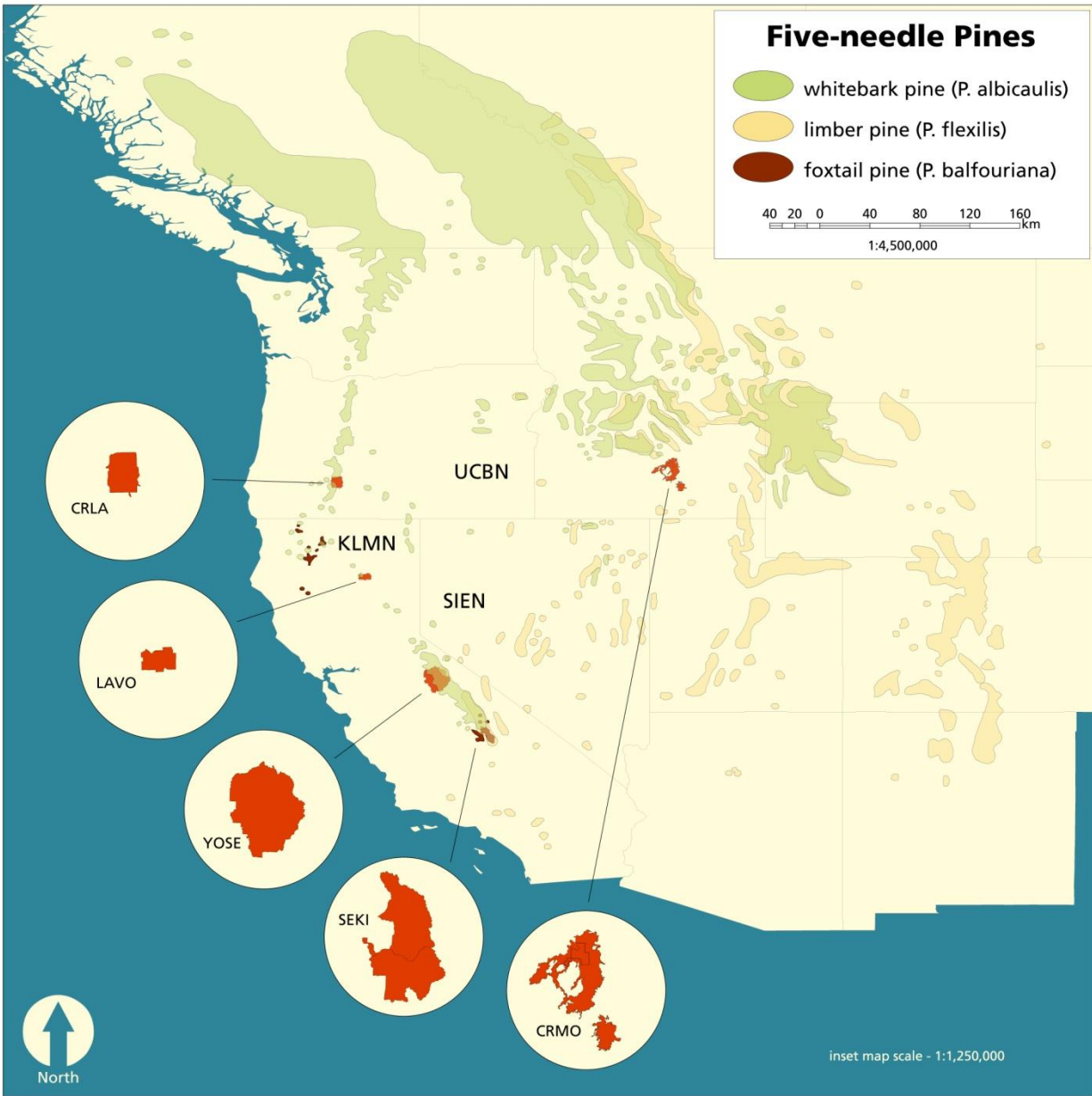


Figure 1. Distribution of whitebark pine, limber pine, and foxtail pine (from Little 1971) and locations of three Pacific West Region networks and associated parks.

Objectives

Limber pine monitoring objectives were established through a collaborative process with 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 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.

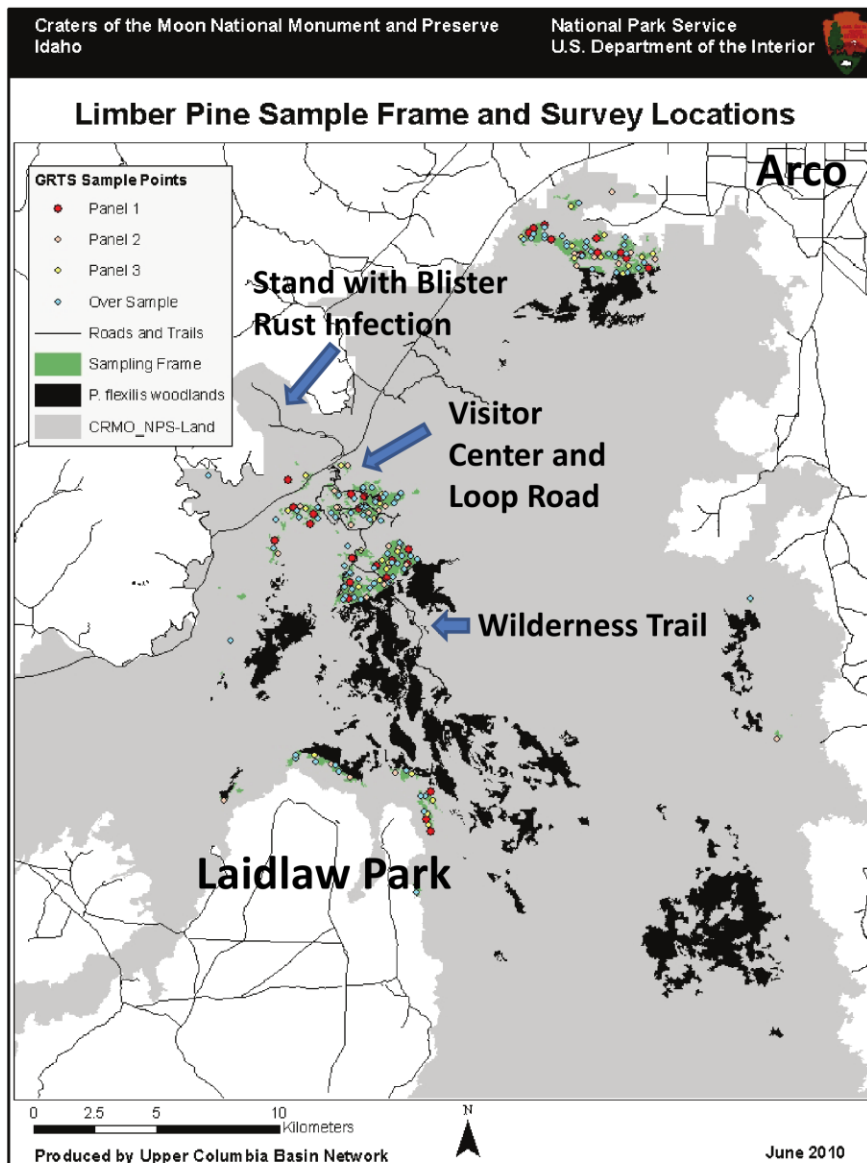


Figure 2. Limber pine monitoring sampling frame and GRTS sample of plot point locations within Craters of the Moon National Monument and Preserve. The sample frame (green) includes all areas of the park within 2 km of roads and trails that have been mapped by Bell et al. (2009) as *P. flexilis* woodland. 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.

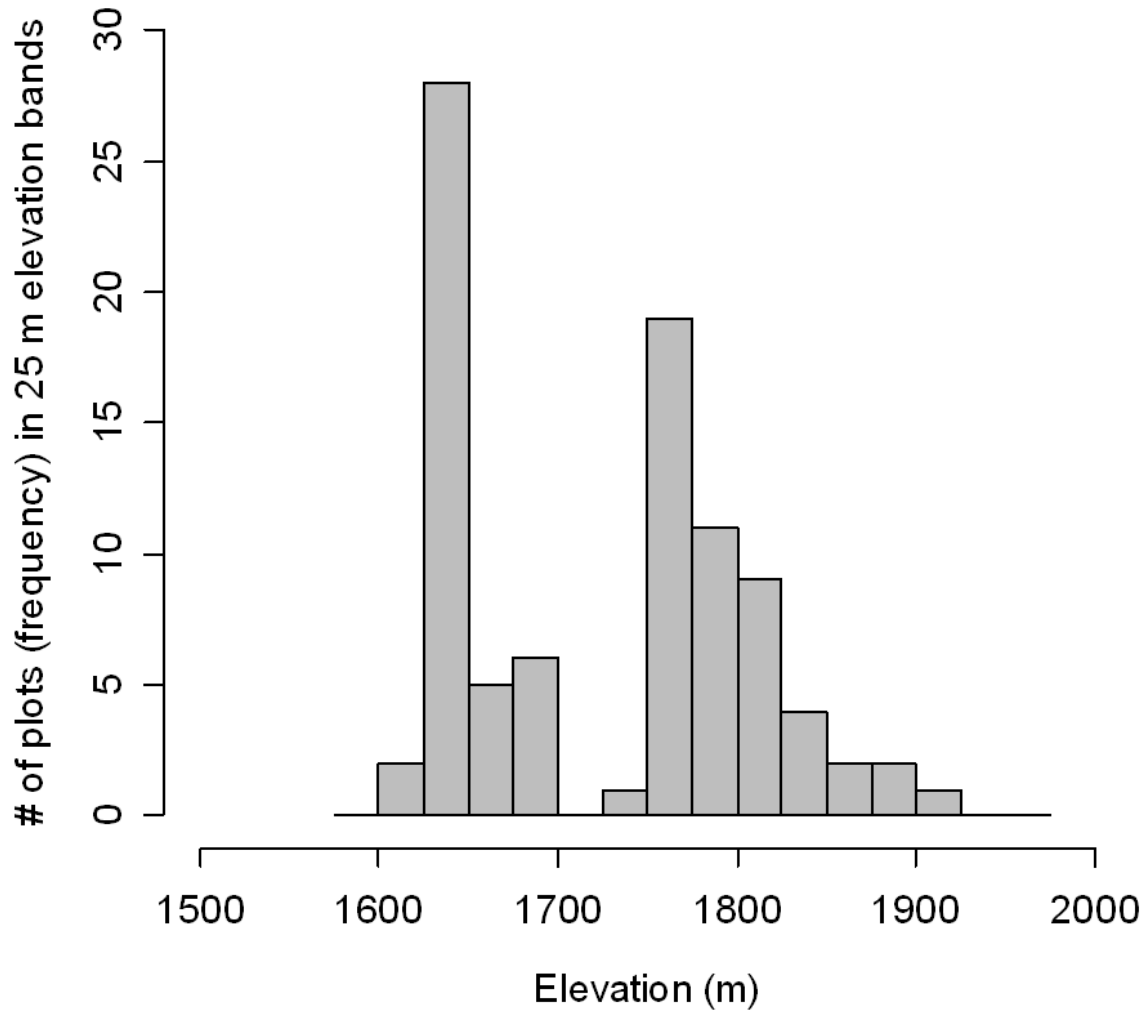


Figure 3. Histogram of elevations represented in the GRTS sample (n=90) for Craters of the Moon National Monument and Preserve.

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 $[1-2^3]$ design, *sensu* McDonald 2003; Table 1). Appendix 1 lists all 30 panel 2 plots plus oversamples that were evaluated and established for monitoring in 2012. In 2012 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 x 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.

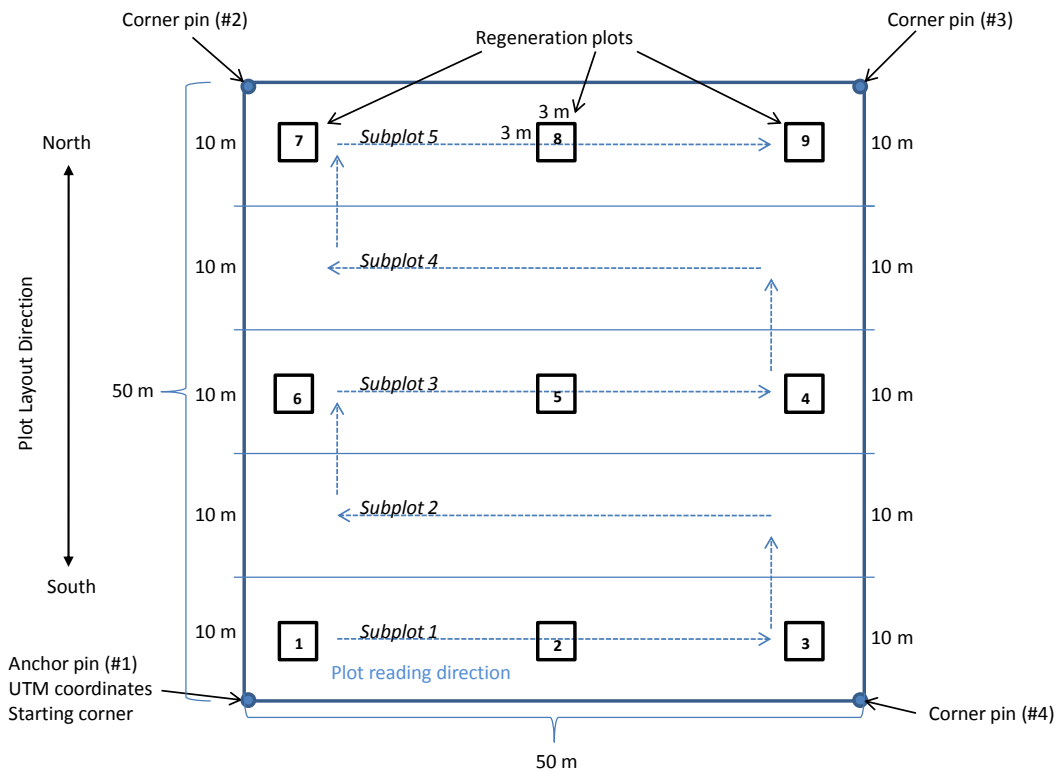


Figure 4. 50 × 50 m macroplot plot with five 10 × 50 m subplots, and nine 3 × 3 m regeneration plots used in UCBN and SIEN white pine monitoring.

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 2012 we installed and sampled 30 plots in Craters of the Moon (Appendix 1). These 30 plots contained a total of 560 live limber pine trees, 38 dead limber pine trees, and 26 Rocky Mountain juniper trees. No Douglas fir (*Pseudotsuga menziesii*) trees were encountered in 2012. No limber pine trees were found with signs of blister rust infection in plots. No live limber pine trees showed signs of attack by pine beetles, but 1 dead limber pine tree showed signs of mountain pine beetle including pitch tubes and J-shaped galleries under the bark. Almost 33% ($n=183$) 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 19, with a maximum of 106 live trees in a plot. About 63% ($n=351$) 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 2012 survey. There appears to be a positive relationship between elevation and basal area within the 2012 plots. A similar positive relationship between elevation and mistletoe infection may also be present. This and other similar kinds of simple graphical analyses will become more informative after additional panels of plots have been surveyed.

A second year of field experience and these preliminary results indicate that the monitoring effort is off to a good start 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). 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 and 2012 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 (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.

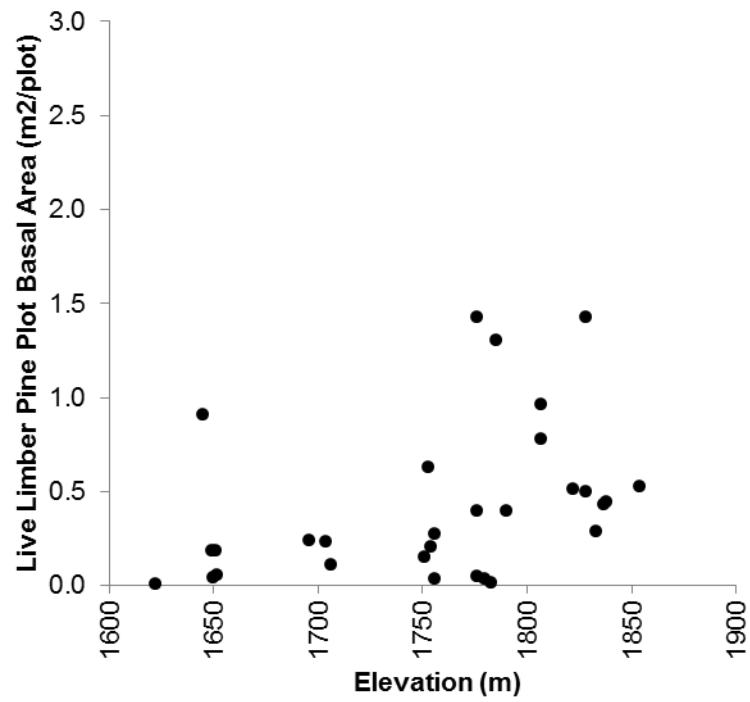
Table 3. Summary table of 2011 and 2012 results for CRMO limber pine monitoring.

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

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).

A)



B)

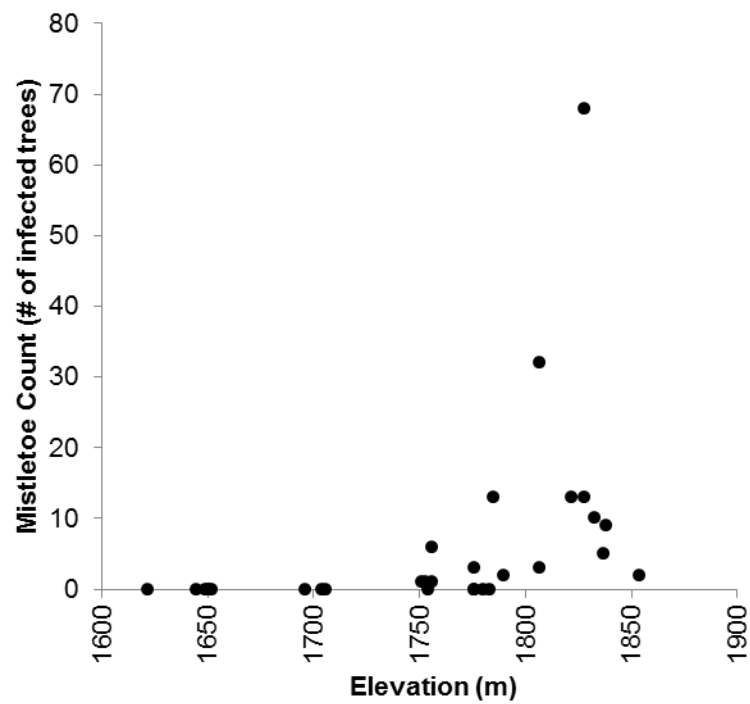


Figure 5. A) Live limber pine basal area (m²) per plot and B) count of trees infected with mistletoe along the elevational gradient captured in the 2012 survey.

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Appendix 1. Plots and oversamples evaluated and established for monitoring in 2012 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 2 sites sampled in 2012 are noted in EvalStatus. Oversample locations provide the replacements for sites dropped during office and field evaluation. Oversample sites 110-112 will become permanent members of panel 2. 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	GRTS wgt	Panel	EvalStatus	EvalNotes
Site-031	291577	4813730	140103	Panel_2	Established	
Site-032	295472	4802778	140103	Panel_2	Dropped	No trees
Site-033	304300	4826526	140103	Panel_2	Dropped	No trees
Site-034	306073	4823807	140103	Panel_2	Dropped	No trees
Site-035	295200	4811218	140103	Panel_2	Established	
Site-036	294765	4813555	140103	Panel_2	Established	
Site-037	302870	4823978	140103	Panel_2	Established	
Site-038	295598	4812002	140103	Panel_2	Dropped	No trees
Site-039	290663	4811750	140103	Panel_2	Dropped	No trees
Site-040	294355	4813440	140103	Panel_2	Established	
Site-041	303580	4823866	140103	Panel_2	Dropped	No trees
Site-042	295179	4812077	140103	Panel_2	Established	
Site-043	293163	4813665	140103	Panel_2	Established	
Site-044	288434	4801641	140103	Panel_2	Established	
Site-045	304577	4823629	140103	Panel_2	Dropped	No trees
Site-046	294304	4809980	140103	Panel_2	Dropped	Steep, unsafe
Site-047	292955	4814363	140103	Panel_2	Established	
Site-048	292834	4803155	140103	Panel_2	Established	
Site-049	302880	4823540	140103	Panel_2	Dropped	No trees
Site_050	311063	4804198	140103	Panel_2	Dropped	No trees
Site-051	295021	4810522	140103	Panel_2	Established	
Site-052	295060	4813705	140103	Panel_2	Established	
Site-053	302769	4824019	140103	Panel_2	Established	
Site-054	295907	4811324	140103	Panel_2	Dropped	No trees
Site-055	293219	4810175	140103	Panel_2	Established	
Site-056	293538	4815390	140103	Panel_2	Established	
Site-057	305092	4824058	140103	Panel_2	Dropped	No trees
Site-058	293668	4812967	140103	Panel_2	Established	
Site-059	293075	4813684	140103	Panel_2	Established	
Site-060	293628	4802601	140103	Panel_2	Established	
Site-091	293447	4810025	140103	Panel_1	Established	Replace site 10
Site-092	294173	4813653	140103	Panel_1	Established	Replace site 18
Site-093	304496	4823236	140103	Panel_1	Established	Replace site 25
Site-094	293645	4810962	140103	Panel_1	Established	Replace site 26
Site-095	295045	4814190	140103	Panel_1	Established	Replace site 29
Site-096	293003	4803076	140103	Panel_2	Established	Replace site 32
Site-097	301546	4824656	140103	Oversample	Dropped	No trees
Site-098	287800	4814990	140103	Panel_2	Dropped	No trees

Table A-1 (continued). Spatially-balanced list of sampling locations for CRMO, organized by panel. Panel 2 sites sampled in 2012 are noted in EvalStatus. Oversample locations provide the replacements for sites dropped during office and field evaluation. Oversample sites 110-112 will become permanent members of panel 2. 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	GRTS wgt	Panel	EvalStatus	EvalNotes
Site-099	295195	4810590	140103	Panel_2	Established	
Site-100	294978	4814063	140103	Panel_2	Established	
Site-101	302472	4824454	140103	Panel_2	Established	
Site-102	295745	4811671	140103	Oversample	Dropped	No trees
Site-103	293382	4810413	140103	Panel_2	Established	
Site-104	295699	4814271	140103	Panel_2	Established	
Site-105	304899	4824020	140103	Oversample	Dropped	No trees
Site-106	294427	4813153	140103	Panel_2	Established	
Site-107	292282	4813212	140103	Panel_2	Established	
Site-108	296658	4801826	140103	Oversample	Dropped	No trees
Site-109	301554	4825113	140103	Panel_2	Established	
Site-110	305403	4823420	140103	Oversample	Established	Replace site 039
Site-111	293677	4810342	140103	Oversample	Established	Replace site 046
Site-112	294642	4814036	140103	Oversample	Established	Replace site 098

Appendix 2. Suggested/required changes to the protocol

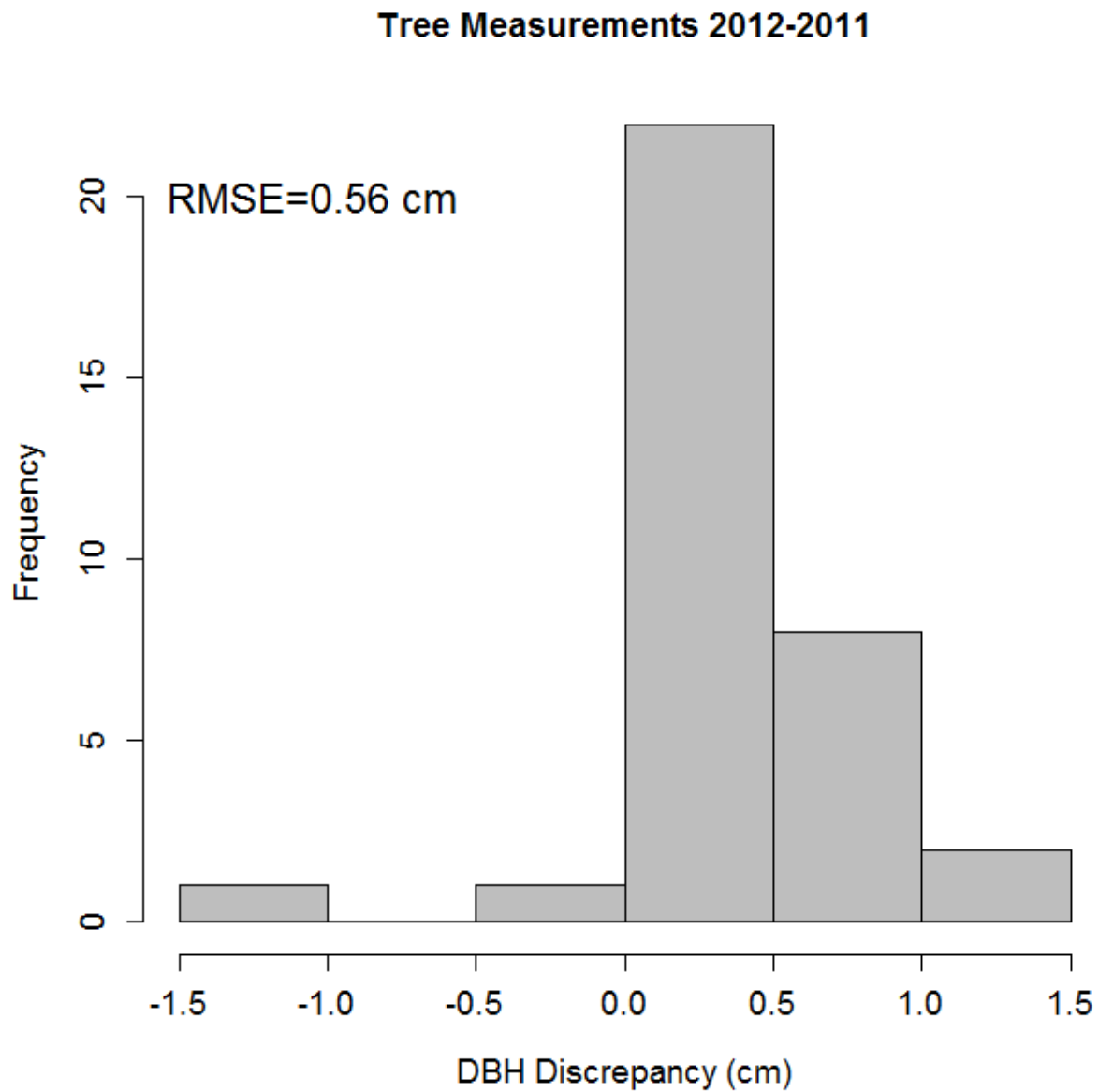
There are several minor changes to the protocol (McKinney et al. 2012) that need to be made to address discrepancies between the narrative and SOPs that address the issue of tagging dead trees and the orientation of plots. Based on the experience in 2012 resurveying plots 96 and 99, we anticipate that a 2-person crew will be sufficient for future monitoring beginning in 2014 when all 90 plots have been established. Two technicians sampled plot 99 in less than two hours. Plot setup, including tagging trees, is often the most labor and time intensive part of the monitoring project. Finally, we note that based on the resurvey of trees in plots 96 and 99 (see Appendix 3) observer differences are relatively minor, but tree heights have discrepancies of some magnitude such that extra care should be given to the task, and that during training extra attention should be provided to this topic.

Appendix 3. Comparison of Tree DBH and Height Measurements from 2011 and 2012

This year two oversample plots 96 and 99 established in 2011 were resampled and rotated in to the 2012 sampling rotation, following the ordered list of spatially-balanced plot locations (see Appendix 1). This provided the UCBN a unique opportunity to test the resurvey procedures of the protocol and also to compare tree DBH and height measurements between two consecutive years of sampling. There was an average discrepancy (root mean square error) of 0.57 cm for DBH based on the resample of 34 trees. All but 2 of the 34 trees showed a positive increase in DBH not exceeding 1.1 cm. This may have been due to tree growth over the past year or possibly to consistent bias resulting from measuring below the tagging nail instead of above, or by wrapping the tape over or under a branch differing from the original measurement. The average discrepancy is small, however. The average discrepancy for tree height was 0.87 m, centered on 0, and range from ± 2.5 m. The centered position of the distribution of these errors indicates there is no consistent bias, effectively resulting in random “noise”. This is probably due to observer error, incorrect height readings, or differences in observer position within plot while taking tree height measurement. It is much more difficult to precisely remeasure tree heights than DBH, even with the use of a laser rangefinder altimeter. An extra effort should be made in the future to strive for accurate and consistent tree measurements by providing time for extra practice during training and also by encouraging observers to approach this task in the field with care and attention.

Figure A-1. Histogram showing overall discrepancies between 2011 and 2012 tree DBH values A) and tree height values B).

A)



B)

