



Upper Columbia Basin Network Limber Pine Community Dynamics 2014 Annual Monitoring Report

Craters of the Moon National Monument and Preserve

Natural Resource Report NPS/UCBN/NRR—2015/1037



ON THE COVER

Photograph of female limber pine (*Pinus flexilis*) cones, Craters of the Moon National Monument & Preserve, Idaho
Photograph by Devin Stucki, NPS.

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Executive Summary

Limber pine (*Pinus flexilis* James) 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). 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 as panel 3. The three extra plots were established because of a mid-season access issue (through private land) 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 2014, a total of 30 plots were revisited, comprising the original 30 from Panel 1 that were established in 2011. This was the first full revisit to panel 1. A total of 403 live limber pine trees and 32 dead limber pine trees, along with 100 other live conifer trees, were sampled in 2014. No incidences of white pine blister rust were found during 2014, although an active white pine blister rust infection can be found in the north end of the monument. Mountain pine beetle attacks were found in 0.5 % of live *P. flexilis* trees ($n=2$). Dwarf mistletoe was found in about 40% of

live limber pine trees ($n=163$). The average number of live limber pine trees per plot was 13.4 with a maximum of 80 live limber pine trees in a plot. Approximately 56 percent of live limber pine trees ($n=227$) had produced female cones. Limber pine seedling regeneration averaged 0.02 seedlings per hectare. These results provide important baseline descriptions of CRMO's unique limber pine population, which occurs on the lower elevation periphery of the species' range.

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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 National Monument and Preserve 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. Dan Esposito's assistance in the field was indispensable for collecting the data presented in this report. This document relies heavily on previous versions of this annual report, as well as the Pacific West Region high elevation pine monitoring protocol (McKinney et al. 2012).

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* E. 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 site in 2012, and a small infected sapling during 2013 (John Apel, personal communication, March 26, 2015).

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). The results reported in this report were generated in 2014 with data collected following an updated protocol by McKinney et al. (2012). In 2014, a total of 30 plots were revisited, comprising the original 30 plots from Panel 1 that were established in 2011. This is the fourth formal year of protocol implementation and the first year of established plot revisits at CRMO.

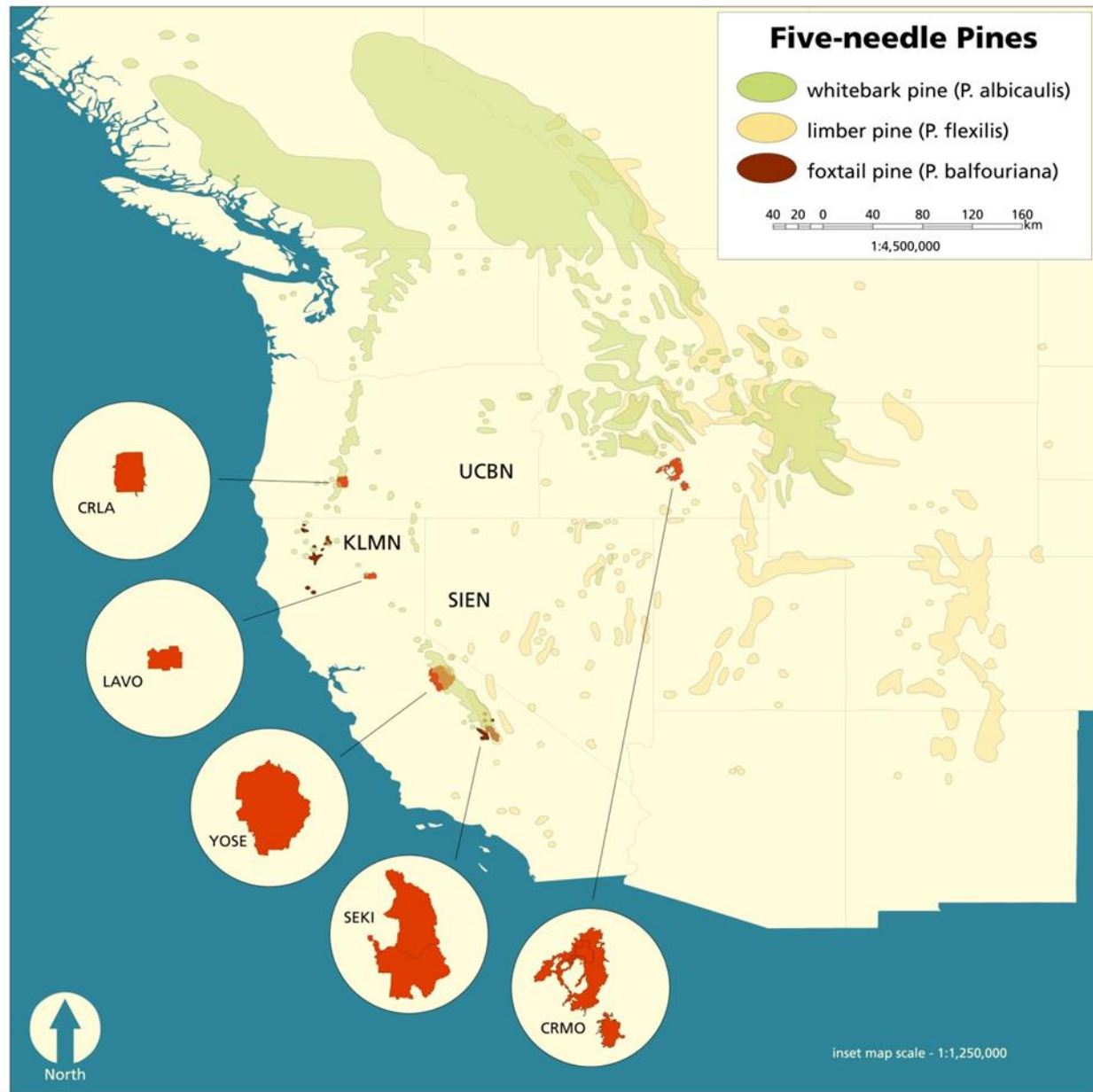


Figure 1. Distribution of whitebark pine, limber pine, and foxtail pine (from Little 1971) and locations of three Pacific West Region networks and associated parks, including CRMO.

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 white pine 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* A. Dietr.) and level of crown kill
4. Incidence of mountain pine beetle (*Dendroctonus ponderosae* Hopkins) 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. 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.

Plot locations 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.

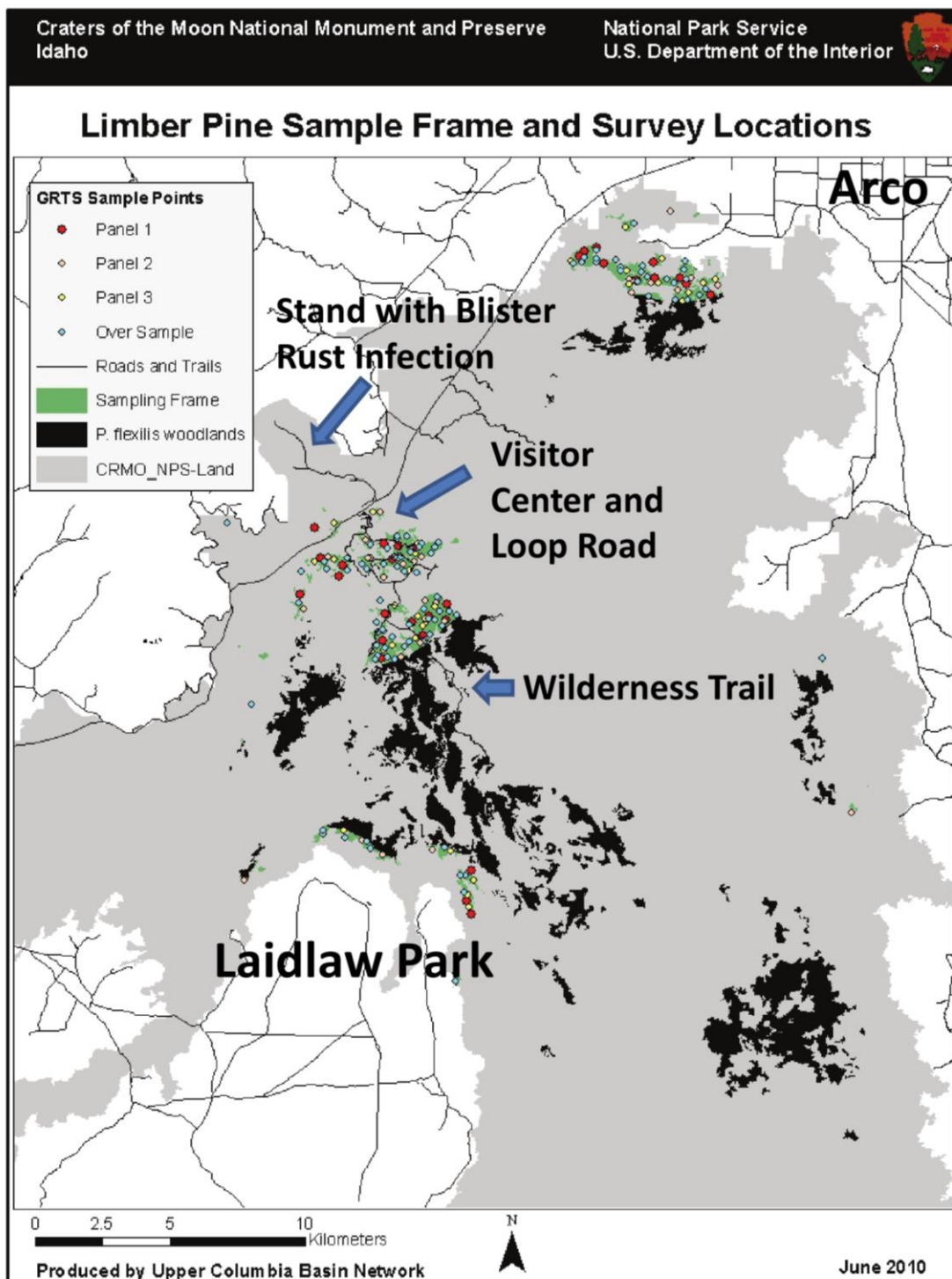


Figure 2. Limber pine monitoring sampling frame and GRTS sample of plot point locations within Craters of the Moon National Monument and Preserve. The sample frame (green) includes all areas of the park within 2 km of roads and trails that have been mapped by Bell et al. (2009) as *P. flexilis* woodland.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

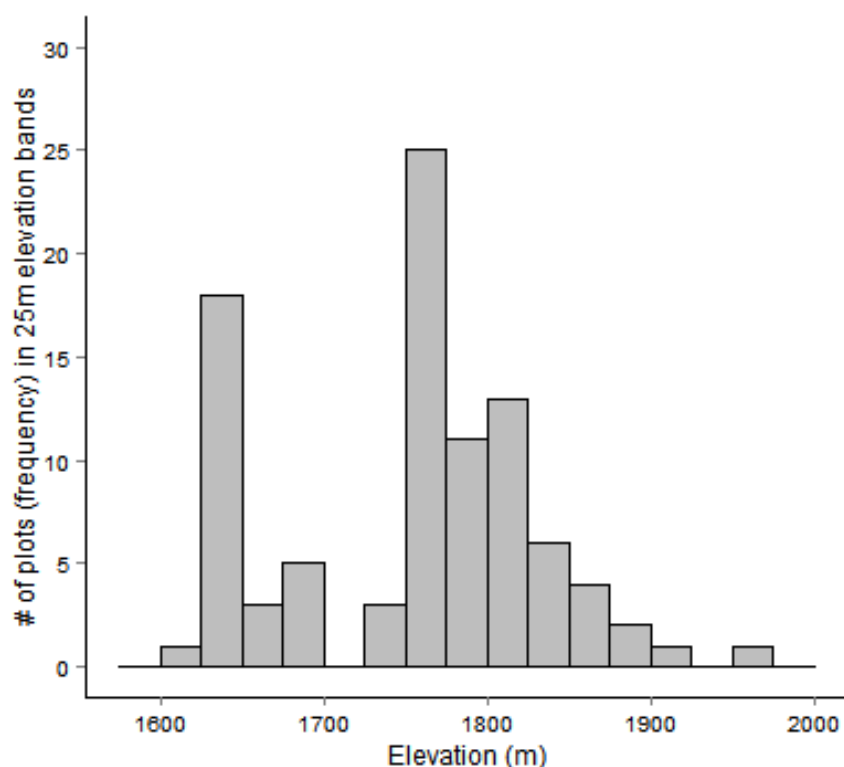


Figure 3. Histogram of elevations represented in the established plots (n=93) for Craters of the Moon National Monument and Preserve.

Frequency and Timing of Sampling

We have adopted a three-year rotating panel design for re-surveying permanent plots in CRMO. The sample of 93 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 1 lists all 30 panel 1 plots plus oversamples that were resampled during 2014. In 2014 all plots were sampled between August 11 and September 3.

Table 1. Revisit design for monitoring limber pine in the Upper Columbia Basin Network. Panel 1 and 2 consist of 30 plots, while 3 additional plots were added to panel 3 for a total of 33 plots. Panels are visited once per 3-year rotation, yielding a total sample size of 93 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 = 33)			x			x			x			x	

Macroplots, consisting of five adjacent 10×50 m subplots (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).

[illegible]

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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 2014 we revisited 30 plots from Panel 1 in CRMO. These plots were established in 2011 and this is the first year that these plots have been resampled (Appendix 1). These 30 plots contained a total of 403 live limber pine trees, 31 dead and 1 recently dead limber pine trees, 42 live Rocky Mountain juniper trees, and 58 live Douglas-fir trees. No limber pine trees were found with signs of blister rust infection in plots, although an active white pine blister rust infection can be found in the north end of the monument. Two live limber pine trees showed signs of attack by mountain pine beetles (pitch tubes).

About 40% ($n=162$) 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 13.4, with a maximum of 80 live trees in a plot (plot 4, Paisley Cone). About 56% ($n=227$) of live limber pine trees produced female cones. Additional summary statistics are reported in Table 3. Figure 5 shows live limber pine basal area per plot (m²/plot) and the percent of live limber pine infected with mistletoe per plot along the elevational gradient captured by the 2014 survey.

A fourth year of field experience and these preliminary 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). 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 2014 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 2011-2014 results for CRMO limber pine monitoring.

Metric	2011 Status ¹	2012 Status ²	2013 Status ³	2014 Status ⁴
Number of established plots	30	30	33	30
Average live <i>Juniperus scopulorum</i> basal area (m ² /ha)	0.51 (0.87)	0.61 (0.31)	0.09 (.06)	0.51 (0.87)
Average live <i>Pinus flexilis</i> basal area (m ² /ha)	1.27(1.33)	1.70 (1.66)	1.92 (2.40)	1.29 (1.38)
Average live <i>Pseudotsuga menziesii</i> basal area (m ² /ha)	22.50 (N/A)	0 (N/A)	0.02 (N/A)	22.66 (N/A)
Average number of <i>J. scopulorum</i> trees/ha	19.50 (20.22)	34.67 (16.65)	14.00 (14.14)	21.00 (22.60)
Average number of <i>P. flexilis</i> trees/ha	50.53 (63.79)	74.53 (95.02)	55.65 (58.90)	53.73 (68.82)
Average number of <i>P. menziesii</i> trees/ha	232 (N/A)	0.00 (N/A)	4 (N/A)	232 (N/A)
Limber pine trees with female cones (%)	69.92 (45.92)	62.80 (48.38)	72.52 (44.70)	56.33(49.66)
Blister Rust Infection Rate (%)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Dwarf Mistletoe Infection Rate (%)	28.50 (45.20)	32.38 (46.83)	49.90 (50.05)	40.20 (49.10)
Mountain Pine Beetle Infection Rate (%)	0.00 (0.00)	0.00 (0.00)	0.42 (6.50)	0.50 (7.04)
Average regeneration of <i>J. scopulorum</i> 20-50cm (seedlings/m ² /ha)	0.01 (0.02)	0.0 (0.0)	0.0 (0.0)	0.01 (0.02)
Average regeneration of <i>J. scopulorum</i> 50-100cm (seedlings/m ² / ha)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Average regeneration of <i>J. scopulorum</i> 100-137cm (seedlings/m ² / ha)	0.01 (0.02)	0.0 (0.0)	0.0 (0.0)	0.01 (0.02)
Average regeneration of <i>P. flexilis</i> 20-50cm (seedlings/m ² /ha)	0.01 (0.03)	0.01 (0.02)	0.01 (0.03)	0.01 (0.02)
Average regeneration of <i>P. flexilis</i> 50-100cm (seedlings/m ² /ha)	0.02 (0.06)	0.01 (0.02)	0.01 (0.02)	0.01 (0.02)
Average regeneration of <i>P. flexilis</i> 100-137cm (seedlings/m ² /ha)	0.0 (0.0)	0.01 (0.02)	0.0 (0.0)	0.0 (0.0)
Average regeneration of <i>P. menziesii</i> 20-50cm (seedlings/m ² /ha)	0.25 (NA)	0.0 (NA)	0.0 (NA)	0.20 (NA)
Average regeneration of <i>P. menziesii</i> 50-100cm (seedlings/m ² /ha)	0.35 (NA)	0.0 (NA)	0.0 (NA)	0.44 (NA)
Average regeneration of <i>P. menziesii</i> 100-137cm (seedlings/m ² /ha)	0.0 (NA)	0.0 (NA)	0.0 (NA)	0.05 (NA)
Limber pine trees with female cones (%)	69.92 (45.92)	62.80 (48.38)	72.52 (44.70)	56.33(49.66)

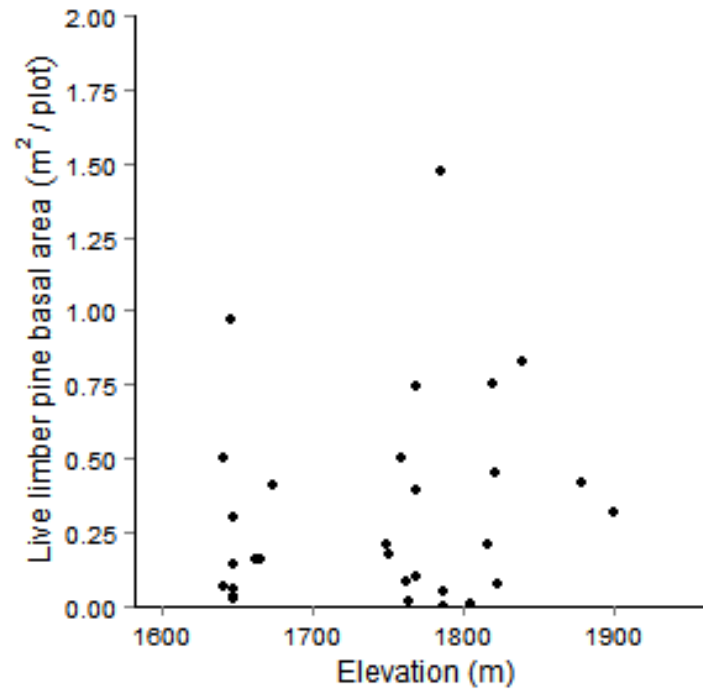
¹Only 8 plots in 2011 with *J. scopulorum* (n=8) and 1 plot in 2011 with *P. menziesii* (n=1).

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.

⁴Only 8 plots in 2014 with *J. scopulorum* (n=8) and 1 plot with *P. menziesii* (n=1).

A)



B)

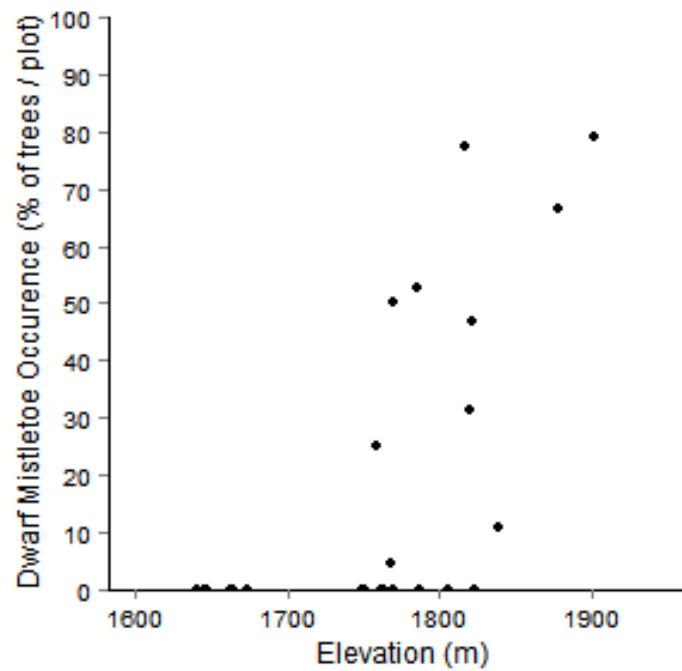


Figure 5. A) Live limber pine basal area (m^2) per plot and B) percentage of trees infected with mistletoe per plot along the elevational gradient captured in the 2014 survey.

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Appendix A. Plots and oversamples evaluated and established for monitoring in 2011-2014 at Craters of the Moon National Monument and Preserve (CRMO).

Table A-1. Spatially-balanced list of established sampling locations for CRMO, organized by panel. 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-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-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-027	291079	4814801	Panel_1	Established		Panel_1
Site-028	296718	4800891	Panel_1	Established		Panel_1
Site-030	293565	4809910	Panel_1	Established		Panel_1
Site-031	291577	4813730	Panel_2	Established		Panel_2
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-040	294355	4813440	Panel_2	Established		Panel_2
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-047	292955	4814363	Panel_2	Established		Panel_2

Table A-1 (continued). Spatially-balanced list of established sampling locations for CRMO, organized by panel. 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-048	292834	4803155	Panel_2	Established		Panel_2
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-055	293219	4810175	Panel_2	Established		Panel_2
Site-056	293538	4815390	Panel_2	Established		Panel_2
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-066	294908	4811493	Panel_3	Established		Panel_3
Site-067	291054	4813537	Panel_3	Established		Panel_3
Site-069	304753	4823217	Panel_3	Established		Panel_3
Site-071	291785	4813612	Panel_3	Established		Panel_3
Site-075	295120	4811155	Panel_3	Established		Panel_3
Site-076	294809	4813860	Panel_3	Established		Panel_3
Site-078	295168	4811396	Panel_3	Established		Panel_3
Site-079	293237	4815406	Panel_3	Established		Panel_3
Site-082	293649	4810222	Panel_3	Established		Panel_3
Site-083	291798	4814981	Panel_3	Established		Panel_3
Site-087	294807	4810705	Panel_3	Established		Panel_3
Site-088	294619	4813224	Panel_3	Established		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-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-103	293382	4810413	Oversample	Established	Replace site 39	Panel_2
Site-104	295699	4814271	Oversample	Established	Replace site 41	Panel_2

Table A-1 (continued). Spatially-balanced list of established sampling locations for CRMO, organized by panel. 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-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-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	Replace site 73	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-122	305605	4823643	Oversample	Established	Replace site 81	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-147	292280	4813651	Oversample	Established	Replace site 77	Panel_3
Site-149	301092	4824809	Oversample	Established	Replace site 85	Panel_3
Site-150	294440	4810351	Oversample	Established	Replace site 89	Panel_3
Site-151	294148	4814375	Oversample	Established	Replace site 113	Panel_3
Site-152	291404	4803376	Oversample	Established	Added for Arco Access Contingency	Panel_3
Site-156	293635	4813441	Oversample	Established	Added for Arco Access Contingency	Panel_3
Site-159	291444	4813532	Oversample	Established	Added for Arco Access Contingency	Panel_3

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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