



Whitebark Pine Conservation Program

2022 Annual Report



**ON THIS PAGE**

Whitebark pine perched along the caldera rim.

Photo by Scott Heisler

ON THE COVER

Growing up: A seedling whitebark pine planted for restoration in 2009 at Rim Village bears a lone seed cone.

Photo by Scott Heisler

Whitebark Pine Conservation Program

2022 Annual Report

Scott E. Heisler and Jennifer S. Hooke

National Park Service
Crater Lake National Park
P.O. Box 7
Crater Lake, Oregon 97604

April 2023

U.S. Department of the Interior
National Park Service
Crater Lake National Park
Crater Lake, Oregon

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

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.

This report received informal peer review by a subject matter expert who was not directly involved in the collection, analysis, or reporting of the data.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available in digital format from the Crater Lake National Park website at:

<https://irma.nps.gov/DataStore/Reference/Profile/2299084>

Please cite this publication as:

Heisler, S.E. and J.S. Hooke. 2023. Whitebark Pine Conservation Program: 2022 Annual Report. Crater Lake National Park, Crater Lake, Oregon.

Contents

	Page
Figures.....	iv
Tables.....	v
Abstract.....	vi
Acknowledgments.....	vii
Introduction.....	1
Methods.....	5
Collection Tree Monitoring.....	5
Verbenone Application.....	6
Long-Term Whitebark Pine Monitoring	6
Whitebark Pine Restoration Plantings.....	7
Controlled Pollination	9
Collection Tree Competition Release Treatment	11
Results.....	12
Collection Tree Monitoring.....	12
Verbenone Application.....	13
Long-Term Whitebark Pine Monitoring	14
Whitebark Pine Restoration Plantings.....	15
Controlled Pollination	18
Collection Tree Competition Release Treatment	19
Discussion	20
Literature Cited	21

Figures

Figure 1. A Clark’s nutcracker perches amidst cones on the characteristically upswept branches of whitebark pine..	1
Figure 2. Recent MPB-caused mortality in whitebark pine. Both trees display signs of potential WPBR infection such as bark stripping from rodent gnawing of WPBR cankers and previously killed crown top (photo on left) and branches (photo on right)..	2
Figure 3. Daily temperature data for CRLA headquarters from January to October of 2022.....	3
Figure 4. Erosion damage on Mt. Scott resulting from an intense monsoonal rainstorm in August 2022.....	4
Figure 5. Conducting WPBR assessments on a collection tree.	5
Figure 6. Location of the park’s seven whitebark pine long-term monitoring plots.	7
Figure 7. Location of CRLA’s six whitebark pine restoration plantings (multiple dots at each site indicate multiple planting blocks).....	8
Figure 8. Clockwise from top left: 1) Pollen extraction at the DGRC. 2) Pollen cones stored in a paper bag. 3) Pollen cones emerging from bud scales. 4) Mature pollen cones.	10
Figure 9. Park staff using loppers to remove a Shasta red fire sapling which was growing up through the crown of a rust-resistant Collection tree.....	11
Figure 10. Left: Survival and mortality of Resistant (A-C), Susceptible (D-F), and Candidate (ratings pending) Collection trees; the y-axis value represents numbers of individual trees. Right: Rust-resistance ratings for the 118 CRLA whitebark pines that have undergone rust-resistance screening trials at the DGRC.	12
Figure 11. A view along Castle Crest in 2022, showing both recent (orange foliage) and past (standing dead) mortality of whitebark pine from MPB attack.....	13
Figure 12. CRLA staff sampling a long-term monitoring plot..	14
Figure 13. Bob Danchok and Angelia Kegley of the DGRC measure the height of a WBP seedling in the Horse Trail restoration planting site.....	15
Figure 15. Location of new proposed roadway at Rim Village running through the existing WBP restoration planting site.....	16
Figure 16. The Rim Village WBP restoration planting during the 2022 season with DGRC staff. A new proposed roadway would destroy most of the current planting site.....	17
Figure 17. Pollen cone collection in 2022.....	18

Figure 18. Before (top left, bottom left) and after (top right, bottom right) removal of WBP competitors.....	19
--	----

Tables

	Page
Table 1. Average blister rust infection rates by size class in 2003 vs. 2022.....	15
Table 2. Survival rates for CRLA’s six whitebark pine restoration planting sites as of 2022.....	17
Table 3. A generalized phenology of pollen cone development in WBP pine during the 2022 season.....	18

Abstract

Major activities of Crater Lake National Park's Whitebark Pine Conservation Program in 2022 supported the park's goals and objectives for conserving and restoring whitebark pine as outlined in the park's Whitebark Pine Conservation Plan. One hundred and twenty-nine trees were subject to annual Collection tree monitoring efforts. This monitoring detected mortality of five Collection trees, three new blister rust infections, and seven new mountain pine beetle attacks (three of these attacks were non-fatal). Sixty-two whitebark pines of management importance were treated with verbenone to help ward off attack by the mountain pine beetle. Results from the park's long-term monitoring plots indicate that whitebark pine is continuing its decline within plot areas, as mature whitebark pine have been reduced by 32.1% from 2003-2022. The park's six whitebark pine restoration plantings were monitored with survival rates ranging from 38.8-75.9% six to thirteen years after planting. A guide for whitebark pine pollen cone phenology monitoring and collection was developed, and pollen collection methodology was pilot tested on five trees. Ten high-value Collection trees underwent a competition release treatment resulting in a total of 58 competing conifers being removed from their driplines.

Acknowledgments

The Crater Lake National Park Whitebark Pine Conservation Program received assistance from the Crater Lake National Park Science and Learning Center to fund a seasonal technician, and from the U.S. Forest Service (USFS) Forest Health Protection (FHP) program to support verbenone treatment to high-value whitebark pine. The USFS Dorena Genetic Resource Center continued to assist the park with blister rust resistance screening, pollen collection, and monitoring the park's six whitebark pine restoration plantings; special thanks go to Richard Sniezko, Angelia Kegley, and Bob Danchok for their continued support. Rob Flowers, Brent Oblinger, Cameron Stauder, and Max Wahlberg of the USFS FHP program provided consultation on forest health and management issues. Casey Allen, Brian Pitt, Eleanor Roeder, Javonn Sims, and Carrie Wyler assisted with sampling the park's long-term whitebark pine monitoring plots.

Introduction

Whitebark pine (*Pinus albicaulis* Engelm.) is a hardy, long-lived species that tolerates the harsh conditions found at the highest elevations of Crater Lake National Park (CRLA). Whitebark pine is considered both a foundation and a keystone species due to the important role it plays in creating and sustaining high elevation vegetation communities (Tomback et al. 2014, 2022). Its seedlings can tolerate full sun and are able to establish in previously tree-less areas, earning whitebark pine the reputation of a colonizing or pioneer species (Tomback et al. 2001). Once established, they ameliorate harsh site conditions and facilitate the establishment of a diverse suite of subalpine species. Whitebark pine stands serve important functional roles such as shading and retaining snowpack and thereby regulating snowmelt, and slowing erosion by anchoring soils in place.

Whitebark pine shares a mutualistic, co-evolved relationship with the Clark's nutcracker (*Nucifraga columbiana*). Whitebark pine is considered a “stone pine” as it bears cones that remain closed at maturity and require animal assistance (typically from Clark's nutcrackers – but also from squirrels, bears, and other mammals) to open cones and extract seeds (Figure 1). The Clark's nutcracker stores whitebark pine seeds in “caches” for future use, relying on a complex spatial memory to enable it to retrieve seeds at a later date. Caches that are not utilized can develop into whitebark pine stands and woodlands.



Figure 1. A Clark's nutcracker perches amidst cones on the characteristically upswept branches of whitebark pine. Photo by Scott Heisler.

Whitebark pine has been declining within CRLA for decades (Beck and Holm 2104). A nonnative pathogen, *Cronartium ribicola*, which causes the disease white pine blister rust (WPBR), was introduced to western North America in 1910. Since that introduction, WPBR has spread throughout the range of whitebark pine with devastating results. Few whitebark pines have genetic resistance to

WPBR, and the disease is progressive and fatal. Warming temperatures and milder winters at high elevations have facilitated a prolonged outbreak of the native mountain pine beetle (MPB – *Dendroctonus ponderosae*). At CRLA, MPB is one of the leading mortality agents for whitebark pine (Smith et al. 2011), and although MPB activity in whitebark pine has waned over the past several years (Smith 2017, Smith 2018) it still causes pockets of mortality on an annual basis (Figure 2). Projected suitable habitat for whitebark pine under different climate change scenarios declines steeply into the future, especially in the Cascade Range (Warwell et al. 2007; Littell et al. 2013). In December 2022, the United States Fish and Wildlife Service listed whitebark pine as a threatened species under the Endangered Species Act (USFWS 2022).



Figure 2. Recent MPB-caused mortality in whitebark pine. Both trees display signs of potential WPBR infection such as bark stripping from rodent gnawing of WPBR cankers and previously killed crown top (photo on left) and branches (photo on right). Photos by Scott Heisler.

In 2003, CRLA applied the first actions in what would become a Whitebark Pine Conservation Program (WPCP) for the park. The Terrestrial Ecology team began by implementing a whitebark pine long-term monitoring program and collecting cones from whitebark pines so that seedlings could be grown and tested for resistance to WPBR at the United States Forest Service (USFS) Dorena Genetic Resource Center (DGRC). Since then, CRLA’s WPCP has expanded to include not only long-term monitoring and rust-resistance screening, but outplanting seedlings grown from rust-resistant “Parent” trees for restoration; applying verbenone, a bark beetle repellent, to high-value whitebark pines; annual monitoring of rust-resistant trees; and researching whitebark pine ecology,

conservation, and decline. This report summarizes major activities of the WPCP in 2022 including: (1) Collection tree monitoring; (2) verbenone application; (3) long-term whitebark pine monitoring; (4) monitoring whitebark pine restoration plantings; (5) controlled pollination efforts; and (6) collection tree release treatment.

Many aspects of whitebark pine biology and health (e.g., seedling mortality and survival; tree vigor; length of growing season) are affected by annual climactic trends. In 2022, CRLA and the region continued to be afflicted by severe drought conditions and CRLA experienced its warmest average daily-high temperature for July-September on record with 2021 being the second warmest (NOAA 2022 – Figure 3). The park received 440” of snow at headquarters (average is 481”) during the 2021—2022 water year (October 1 – September 30), which is 91% of average. Mid- and late-winter snowfall levels were dramatically low, with CRLA having received only 33% of average at the end of March. A series of heavy spring storms combined with cooler than average spring temperatures resulted in the first snow-free date at headquarters occurring on July 1st. The total amount of precipitation (melted) received at headquarters was 62” (average is 65”), which is 95% of average.

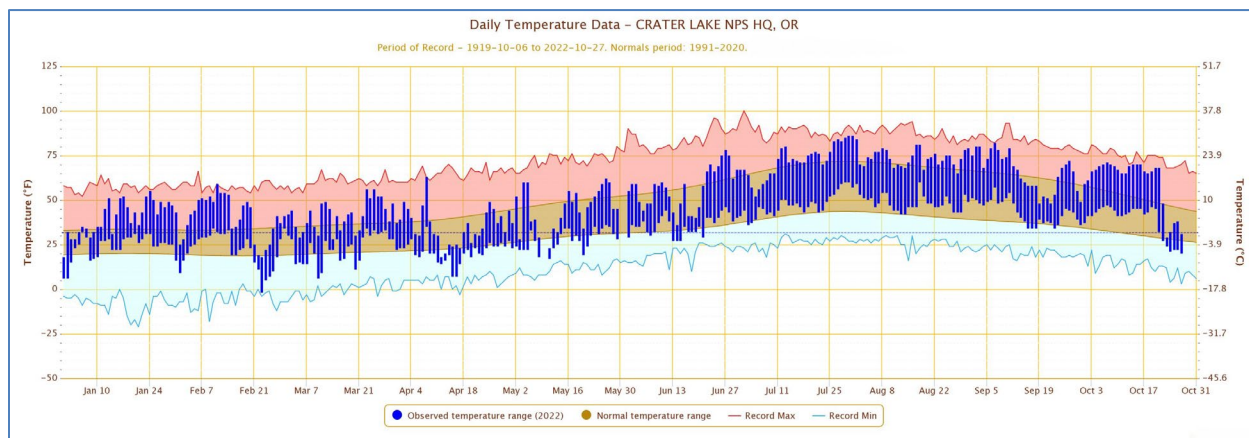


Figure 3. Daily temperature data for CRLA headquarters from January to October of 2022. Data displayed are daily temperature range (blue), daily average range (brown), and record max (red) and minimum (blue) temperatures for January through October of 2022.

Also of note was the occurrence of several intense monsoonal storm systems that affected the region during July and August. Torrential rain from a particularly intense storm cell resulted in localized surface erosion and rilling from runoff on the steep pumice slopes of Mt. Scott, an area containing CRLA’s largest contiguous block of whitebark pine habitat. Examination of the slopes revealed large areas where nearly all fine surface soil and understory vegetation (excepting species with deep taproots) had been washed away, and areas where roots of mature whitebark pine had been exposed and abraded by the formation of gullies (Figure 4). A continuing pattern of these intense summer storms and accompanying erosive damage would likely have significant implications for the establishment of whitebark pine seedlings and the health of established trees.



Figure 4. Erosion damage on Mt. Scott resulting from an intense monsoonal rainstorm in August 2022. Clockwise from top left: 1) deep runoff-created rills surrounding mature whitebark pine; 2) roots of mature whitebark pine exposed and abraded by runoff; 3) an area where surface runoff flows scoured away most of the upper soil layers and all understory vegetation; and 4) deposition of eroded soil particles at the base of Mt. Scott; this rock-hard crust of deposited material is several inches thick and entombs low-growing vegetation. Photos by Scott Heisler.

Methods

Collection Tree Monitoring

The DGRC has been assessing CRLA whitebark pines' levels of resistance to WPBR since 2003. The rust-resistance screening process currently takes seven years to complete; two-year-old seedlings are inoculated with *C. ribicola* at the DGRC, monitored for five years, and then assigned a resistance rating of A-F (much like grades in school) with "A" showing the most resistance and "F" the least. Collection trees are given a rating of A-F based on the rust-resistance of their progeny. Trees that receive A-C rust-resistance ratings are deemed "Resistant" trees. Trees that receive "D," "E," and "F" ratings are considered "Susceptible" trees; and trees whose progeny are currently undergoing rust-resistance screening trials are called "Candidate" trees. While the most rust-resistant trees are considered "A" and "B" trees, "C" trees are considered moderately resistant and included in the definition of Resistant trees to include more genetic diversity for restoration purposes. All Resistant and Candidate trees are monitored on an annual basis (Figure 5). Staffing levels allowed all Collection trees to be monitored in 2022.



Figure 5. Conducting WPBR assessments on a collection tree. Photo by Scott Heisler.

Annual Collection Tree Monitoring entails assessment for WPBR, MPB, dwarf mistletoe, and other damage; assessing the cone crop; and photographing the tree and any notable features (e.g., cankers). Parameters such as diameter at breast height (DBH), tree height, assessment of non-whitebark pine

conifer competitors, and spatial coordinates are updated every five years, as was done in 2022. A complete account of the Collection Tree Monitoring program is available in the Crater Lake National Whitebark Pine Conservation Plan (Beck and Holm 2014). Typically, verbenone application to Resistant and Candidate trees occurs concurrently with Collection Tree Monitoring.

Verbenone Application

The MPB utilizes a group attack strategy to kill a host tree. When a female beetle finds a suitable host, she emits an aggregating pheromone that invites other beetles to colonize the host. Conversely, when the host tree has been fully colonized, beetles produce an anti-aggregating pheromone to alert other beetles to look for a different host. Verbenone is a synthetic form of the anti-aggregating pheromone, and it has been applied as a bark beetle repellent to high-value whitebark pines at CRLA since 2004. To apply verbenone pouches to a tree, two 7g pouches are stapled to the north side of the bole as high up as the applicator can reach while spacing the pouches at least one vertical foot apart. Trees with DBH > 100 cm often have four verbenone pouches attached when supplies allow. Verbenone is applied annually from May through July to all living Resistant and Candidate trees with the exception of trees with < 15 cm DBH. Timing of verbenone application is often dictated by snowmelt and road opening progression that allows access to trees. Pouches remain attached until the following spring/summer when they are removed and replaced with fresh pouches.

Since many Collection trees are found in or near high visitor-use areas (near trails, pullouts, overlooks, etc.), a small, laminated note is attached to trees treated with verbenone alerting park visitors of the treatment purpose and telling them to not touch the verbenone. In years with low verbenone supplies due to budgetary constraints, “C” rated Resistant trees may not be treated. The full CRLA Verbenone Treatment Plan is available in the park’s Whitebark Pine Conservation Plan (Beck and Holm 2014).

Long-Term Whitebark Pine Monitoring

Crater Lake National Park implemented a long-term monitoring program in 2003 to track changes in whitebark pine communities. Seven plots were strategically placed in areas representing different whitebark pine-dominated vegetation types throughout the park (Figure 6). With the exception of 2008, plots have been sampled annually since 2003. These plots track changes in tree health and density, understory vegetation cover, and substrate cover. Tree data are collected annually (with the exception of data on DBH, tree height, and canopy position, which are collected every five years); understory vegetation data are collected every other year; and substrate cover data are collected every five years. Parameters collected annually on individual trees include tree health, blister rust infection and presence of active and inactive cankers, MPB attack and severity, presence of cones, presence of mammal damage (e.g., gnawing) and severity, and any additional damage (e.g., chlorosis, mechanical damage) that may have affected the tree. Understory vegetation and substrate data are collected using a relevé approach encompassing the entire plot. In 2022, plots were sampled from August 17 – September 1. Data collected this year included DBH, tree height, canopy position, substrate cover, and understory vegetation cover.

This CRLA-based long-term monitoring effort is separate from and complementary to the Vital Sign long-term monitoring of whitebark pine implemented in 2012 by the National Park Service (NPS)

Klamath Inventory and Monitoring Network (KLMN). The KLMN effort established 30 whitebark pine long-term monitoring plots throughout CRLA utilizing a peer-reviewed protocol employed by several NPS units in the Pacific West region. Information on this effort is available here:

<https://www.nps.gov/im/klmn/whitebark.htm>

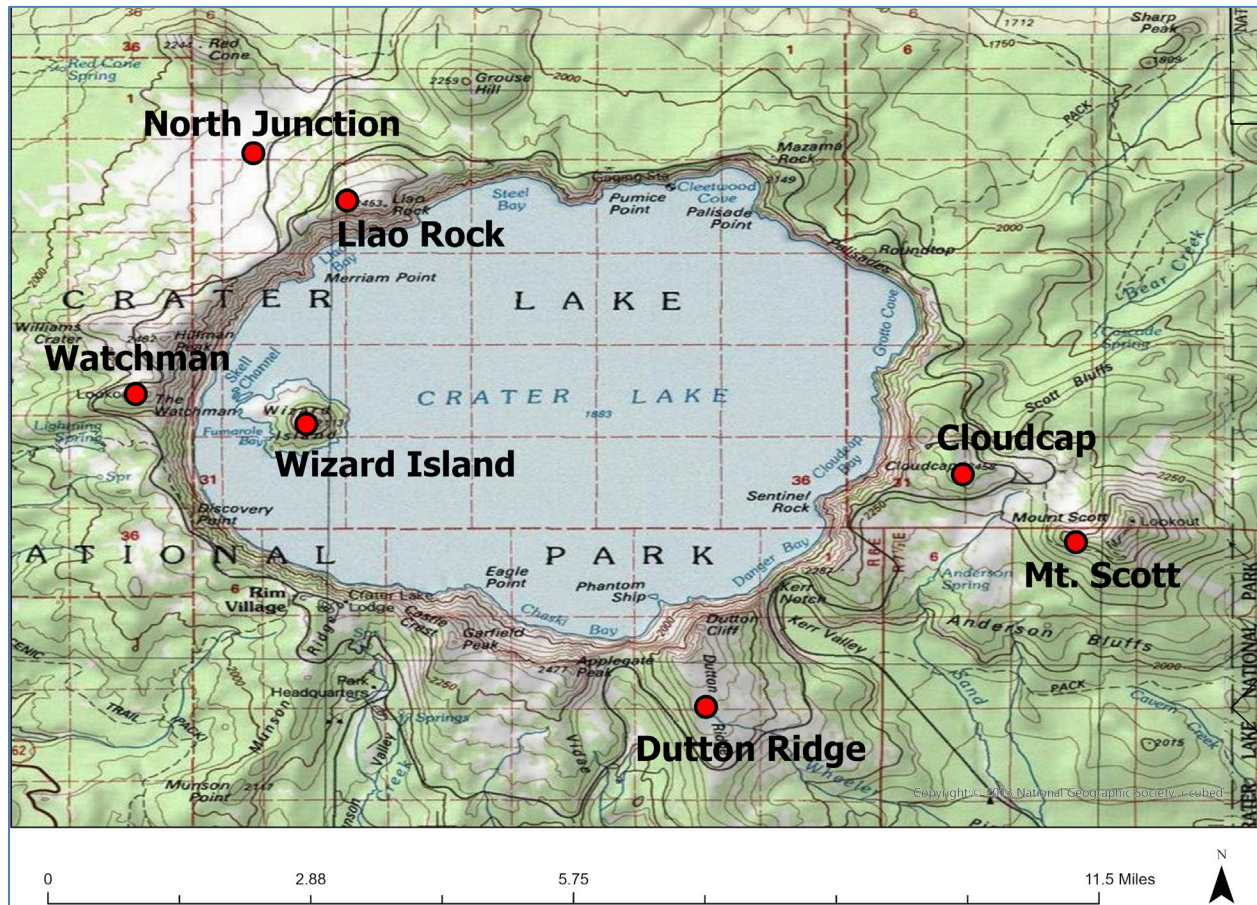


Figure 6. Location of the park's seven whitebark pine long-term monitoring plots. Map by Jen Hooke.

Whitebark Pine Restoration Plantings

The park has conducted six whitebark pine restoration plantings: the Rim Village, Horse Trail, Dutton Ridge, North Junction, Grouse Hill, and Scott Bluffs plantings (Figure 7). Each planting effort utilized two- or three-year-old seedlings sourced from CRLA Parent trees grown by the DGRC. Seedlings are monumented with small metal tags inserted at ground level and mapped to ease relocation using a sub-meter accuracy GPS unit. Seedlings are monitored annually for WPBR infection, vigor, growth, and damage as a joint effort between CRLA and the DGRC.

The 2009 Rim Village planting utilized an opportunity to restore the site of a former parking lot between the Rim Village Café and Gifts building and the Rim Village promenade. Three hundred and thirty-two seedlings were planted from 17 Resistant and Susceptible CRLA Parent trees. Susceptible seedlings were included in the restoration planting as a field validation of rust-resistance results determined by the DGRC. Since the planting site was a former parking lot, soils were highly compacted, and a backhoe and auger were used to drill planting holes. Boulders, woody debris, and

forest litter and duff were added to ameliorate the harshness of the planting site. Between one and three seedlings were placed together in a planting hole. Seedlings were planted from September 15 – 23, 2009, and watered as needed until snowfall on October 1.



Figure 7. Location of CRLA's six whitebark pine restoration plantings (multiple dots at each site indicate multiple planting blocks). Map by Jen Hooke.

The 2009 Horse Trail planting, located just south of Rim Village, is both a restoration project and an experiment to determine if inoculating seedlings with a beneficial fungal endophyte increases their chance of survival. Endophytes are fungal species that live inside plants and may confer benefits to their host such as resisting infection from WPBR. One hundred ninety-two seedlings were planted at the Horse Trail site from five Resistant and Susceptible CRLA Parent trees. One half of the seedlings were inoculated with the endophyte *Myrothecium roridum*, the other half were treated with distilled water as controls. Seedlings were randomized and planted in five circular “family” (i.e., from the same Parent tree) plots; seedlings were planted one or two to a planting hole and seedlings with differing treatments were not planted in the same planting hole. No ameliorations were made to the site prior to planting. Seedlings were planted on September 28, 2009, and watered immediately after planting.

The 2012 Dutton Ridge and North Junction plantings were part of a USFS Forest Health Protection (FHP) funded project involving CRLA, DGRC, the Deschutes National Forest, and Oregon State University. A total of 416 seedlings were planted at both sites. Seedlings originated from ten CRLA Parent trees; eight of these Parent trees were Resistant and two were Susceptible. The rationale for including Susceptible trees in the restoration planting is again to field-validate rust-resistance results determined by the DGRC. This project incorporated a randomized block design with the number of seedlings from each Parent tree divided as equally as possible among the blocks. Due to more area available for planting at Dutton Ridge vs. North Junction, five blocks were placed at Dutton Ridge with three blocks at North Junction. Fifty-two seedlings were assigned to each block. Seedlings were planted one to a planting hole, and planting hole locations were determined based on proximity to naturally occurring ameliorating microsite features such as downed wood and rocks. Seedlings were planted on October 18, 2012, and received no watering. Immediately after planting, CRLA experienced a series of storms and received 27" of snow from October 19 – 25, 2012. In 2013, 130 naturally occurring whitebark pine seedlings of similar size to planted whitebark pine seedlings at the Dutton Ridge and North Junction sites were tagged, mapped, and assessed for height, vigor, WPBR infection, and damage. These "natural regeneration" seedlings are included in the annual monitoring of this restoration project.

Two restoration plantings occurred in 2016 at Grouse Hill and Scott Bluffs. These sites were selected based on having high levels of overstory whitebark pine mortality and little natural regeneration. A total of 484 seedlings were planted at both sites. Seedlings originated from sixteen CRLA Parent trees; fourteen of these Parent trees were Resistant and two were Susceptible. The rationale for including Susceptible trees in the restoration planting is again to field-validate rust-resistance results determined by the DGRC. This project incorporated a randomized block design with the number of seedlings from each Parent tree divided as equally as possible among the blocks. Four blocks were placed at Grouse Hill with four blocks at Scott Bluffs. The number of seedlings assigned to each block ranged from 59-61. Seedlings were planted one to a planting hole, and planting hole locations were determined based on proximity to naturally occurring ameliorating microsite features such as downed wood and rocks. Seedlings were planted on October 11-12th and received no watering. Immediately after planting, CRLA experienced a series of storms, and the planting sites were covered by over a foot of snow.

Controlled Pollination

Increasing levels of genetic resistance to blister rust in whitebark pine populations is key to maintaining this foundation and keystone species within CRLA and throughout its range. A controlled pollination study (Figure 8) was initiated at CRLA in 2022 and will serve as the first attempt in whitebark pine to test the levels of rust-resistance resulting from a cross between confirmed rust-resistant trees, and also how resistance is affected by crossing confirmed resistant trees with pollen from confirmed susceptible trees. This will help managers understand how rust resistance may be distributed across the landscape over time, and also whether there is a benefit to controlling pollination to achieve greater degrees of rust-resistance in resulting progeny.

The park has been testing whitebark pine Parent trees for resistance to blister rust since 2003 and has confirmed trees with high to low levels of rust resistance. For this project, approximately 10-20 rust-resistant trees will be crossed with pollen from confirmed resistant and susceptible trees. The resulting seed cones will be collected upon maturity and sent to the DGRC for seed extraction and seedling production. The resulting seedlings will then be screened for rust resistance using standard DGRC methodology via inoculation with *C. ribicola* and subsequent assessment for blister rust symptoms and overall survival. A comparison will be made of the rust resistance ratings from 'resistant x resistant' seedlings vs. 'resistant x susceptible' seedlings. This information may yield critical information on how seedlings from resistant trees may confer resistance to their progeny based on the levels of resistance found in their pollen source.



Figure 8. Clockwise from top left: 1) Pollen extraction at the DGRC. Photo by Angelia Kegley. 2) Pollen cones stored in a paper bag. 3) Pollen cones emerging from bud scales. 4) Mature pollen cones. Photos 2-4 by Scott Heisler.

Efforts in 2022 focused on developing pollen cone phenology monitoring protocols, orienting staff to pollen collection techniques and timeframes, and collecting pollen for use in 2023. Phenology of candidate trees and surrounding areas was monitored from May through July. Staff from the DGRC visited the park in late July to instruct park staff on pollen cone collection techniques. Methodology used for both phenology monitoring and pollen cone collection are detailed in a summary document (Heisler and Hooke 2022). Pollen cones were transferred to the DGRC for drying, pollen extraction, and storage.

Collection Tree Competition Release Treatment

Collection tree monitoring efforts identified ten high-value whitebark pines being threatened by competition from non-whitebark pine conifers growing within their driplines. All of these competing conifer species grow taller than whitebark pine and have the potential to shade out the whitebark pines over time, leading to reductions in growth and eventual mortality of these ten whitebark pines. Since nine of these whitebark pines are confirmed to have resistance to the disease white pine blister rust (the tenth whitebark pine is currently undergoing blister rust screening trials and has potential resistance), these trees serve as part of the link to the future of whitebark pine's continued existence within CRLA. Reducing competing species within the driplines of these ten trees is another way to protect the limited genetic resistance to WPBR present within CRLA's whitebark pine communities.

Competing conifer species included small seedling, sapling, and understory mountain hemlock (*Tsuga mertensiana*), subalpine fir (*Abies lasiocarpa*), and Shasta red fir (*Abies magnifica* x *Abies procera*). These trees were removed using a handsaw and loppers, and were flush-cut as close to ground level while not causing ground disturbance (Figure 9). Cut competitor trees were hand-carried from the dripline (as to not contribute to fuel loadings near these high-value trees) and scattered near adjacent non-whitebark pine tree canopies in a manner that did not greatly increase fuel loadings (no "jackpotting" of cut fuels).



Figure 9. Park staff using loppers to remove a Shasta red fir sapling which was growing up through the crown of a rust-resistant Collection tree. Photo by Scott Heisler.

Results

Results are presented separately for each component of 2022 WPCP activities.

Collection Tree Monitoring

One hundred twenty nine Collection trees were monitored in 2022, which encompassed all known living Resistant, Susceptible, and Candidate trees as of June 2022. Five Collection trees were found dead in 2022; all of these were infrequently monitored Susceptible trees that appeared to have been dead for over a year. Eighteen Collection trees have died since 2003; seven were Resistant trees, ten were Susceptible trees, and one tree was unrated due to insufficient yields of viable seed enabling testing. The park has lost seven of its 44 Resistant trees (15.9%), five due to MPB and two to WPBR (Figure 10). Ten out of 73 Susceptible trees (13.7%) have died; six from MPB, three from WPBR, and one from unknown causes (Figure 11). Rust-resistance screening results have been received from 117 Collection trees to date. Twenty-four trees are “Candidate” trees, which means their rust resistance ratings are pending. Rust resistance at CRLA is promising so far with 37% of tested trees (n=117) showing some degree of resistance (Figure 10), although sample sizes are small, and more results will contribute to a better understanding of resistance and how it varies across CRLA whitebark pine habitat.

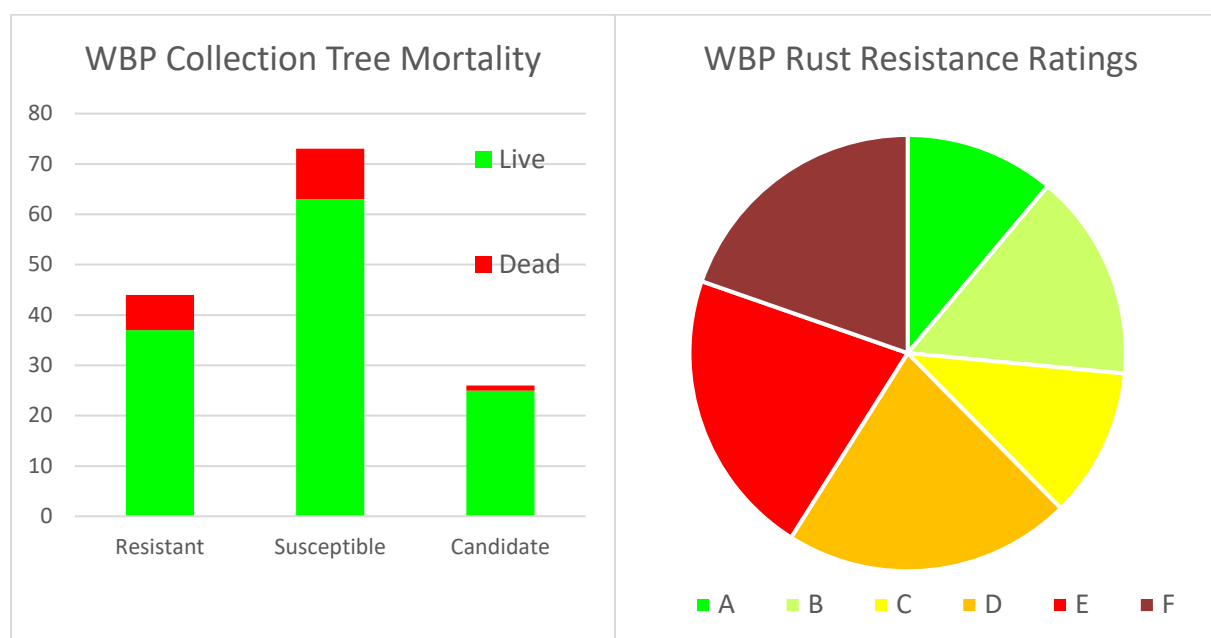


Figure 10. Left: Survival and mortality of Resistant (A-C), Susceptible (D-F), and Candidate (ratings pending) Collection trees; the y-axis value represents numbers of individual trees. Right: Rust-resistance ratings for the 118 CRLA whitebark pines that have undergone rust-resistance screening trials at the DGRC.

In addition to the field work component of monitoring CRLA’s collection trees, significant data management work was conducted in 2022. This consisted of digitizing all paper records documenting Collection tree monitoring and cone collection activities for all 143 trees included in

the program, and reorganizing existing digital records and photographs for these trees. The intent of this effort was to safeguard the 20 years' worth of Collection tree monitoring information contained in these paper documents from destruction by wildfire, rodents, etc., as well as to streamline access to the data and enable its use in the field on tablet computers.

Verbenone Application

Verbenone was applied to 62 Resistant and Candidate trees (including one Susceptible tree – NJ01 – due to its good health and legacy tree status) from June 6 – July 20. All trees had two pouches applied except for large-diameter trees NJ01, NJ02, and AM06 which had four pouches attached. Collection tree monitoring in 2022 revealed one confirmed recent death due to MPB attack (WP01), three trees killed by MPB attack over one year ago (RV09, RV07, RV06), and one tree which had lost all of its crown except one ground level branch due to MPB attack (MS03). Two trees treated with verbenone in 2021 were found to have sustained minor MPB attack (DR06, CP02).

The MPB outbreak that has been impacting CRLA's whitebark pine since at least 2003 had subsided; however, pockets of ongoing MPB mortality continued to persist. Often the largest-diameter trees are killed, making this background or endemic-level MPB-caused mortality especially insidious. While the annual MPB-caused mortality of whitebark pine is concerning, the cumulative impacts of the last two decades of MPB attack have been devastating to CRLA's whitebark pine communities (Figure 11). Observations in 2022 indicated that levels of MPB mortality in CRLA's whitebark pine were again ticking upwards compared with recent years. The U.S. Forest Service Forest Health Protection (FHP) staff was consulted on this issue, and they recommended applying verbenone to legacy whitebark pine in 2023. The FHP will provide additional verbenone to the park to support this effort.



Figure 11. A view along Castle Crest in 2022, showing both recent (orange foliage) and past (standing dead) mortality of whitebark pine from MPB attack. Photo by Scott Heisler.

Long-Term Whitebark Pine Monitoring

The park's seven long-term whitebark pine monitoring plots were sampled from August 17 – September 1, 2021 (Figure 12). Fresh MPB activity was not observed within any of the plots but was present just outside all plots except the Wizard Island plot. All plots continue to be impacted by WPBR; additionally, the Wizard Island plot continues to be devastated by dwarf mistletoe. Mortality of seedlings within plot areas in 2022 was caused by animal predation, drought/desiccation, and unknown causes. It is suspected that one missing seedling in the Mt. Scott plot was buried or washed away by a debris flow resulting from intense rain events in August.



Figure 12. CRLA staff sampling a long-term monitoring plot. Photo By Carrie Wyler.

The number of overstory whitebark pines (> 15 cm DBH) within plot areas have been reduced by 32.1% from 2003 to 2022; average blister rust infection rate in this size class has changed from 13.2% in 2003 to 31.9% in 2022. The number of sapling whitebark pines (> 0 and < 15 cm DBH) have increased by 10.3% during this period due to recruitment; average blister rust infection rate in this size class has changed from 7.4% in 2003 to 14.7% in 2022. The total number of live whitebark pine (> 0 cm DBH) has been reduced by 8.3% from 2003 to 2022; the average blister rust infection rate across all size classes has changed from 9.9% in 2003 to 20.3% in 2022. Within plot areas, large WBP have been drastically reduced; a 46.4% reduction in trees > 25 cm DBH has been experienced from 2003 to 2022. Average blister rust infection in this > 25 cm DBH size class has changed from

14.3% in 2003 to 43.3% in 2022. Comparison of blister rust infection rates by size class from 2003 to 2022 are presented in Table 1.

Table 1. Average blister rust infection rates by size class in 2003 vs. 2022.

WBP Size Class	2003 WPBR Infection Rate	2022 WPBR Infection Rate
Understory (> 0 but < 15 cm DBH)	7.4%	14.7%
Overstory (> 15 cm DBH)	13.2%	31.9%
Large Overstory (> 25 cm DBH)	14.3%	43.3%
All Trees (> 0 cm DBH)	9.9%	20.3%

Whitebark Pine Restoration Plantings

The park's six whitebark pine restoration plantings were monitored from August 1-4 with assistance from the DGRC (Figure 13). The park's six established whitebark pine restoration plantings continued to do relatively well six to thirteen years after planting. Despite continued issues with visitor trampling, the Rim Village site continues to have the highest survival rate of any of CRLA's six restoration planting sites. The 2022 survival rates for planted seedlings range from 31.8% to 75.9% and are displayed in Table 2.



Figure 13. Bob Danchok and Angelia Kegley of the DGRC measure the height of a WBP seedling in the Horse Trail restoration planting site. Photo by Scott Heisler.

A troubling development has emerged that may drastically impact the Rim Village WBP restoration planting site. The park has determined that the removal of the parking lot and subsequent rerouting of traffic related to the 2009 Rim Village Café and Gifts remodel project has resulted in increased traffic congestion at Rim Village. Park and Denver Service Center staff have proposed to reinstall a

roadway in the restored parking lot area (Figure 14), which would have impacts to approximately two thirds of the WBP planted for restoration (Figures 15 and 16). Given that this is the park's most successful of all the restoration plantings conducted to date coupled with the value of this restoration planting for interpreting WBP to park visitors, plus given WBP's recent listing status, all efforts will be made to relocate existing WBP using tree spading techniques into adjacent unaffected areas if this proposal moves forward.

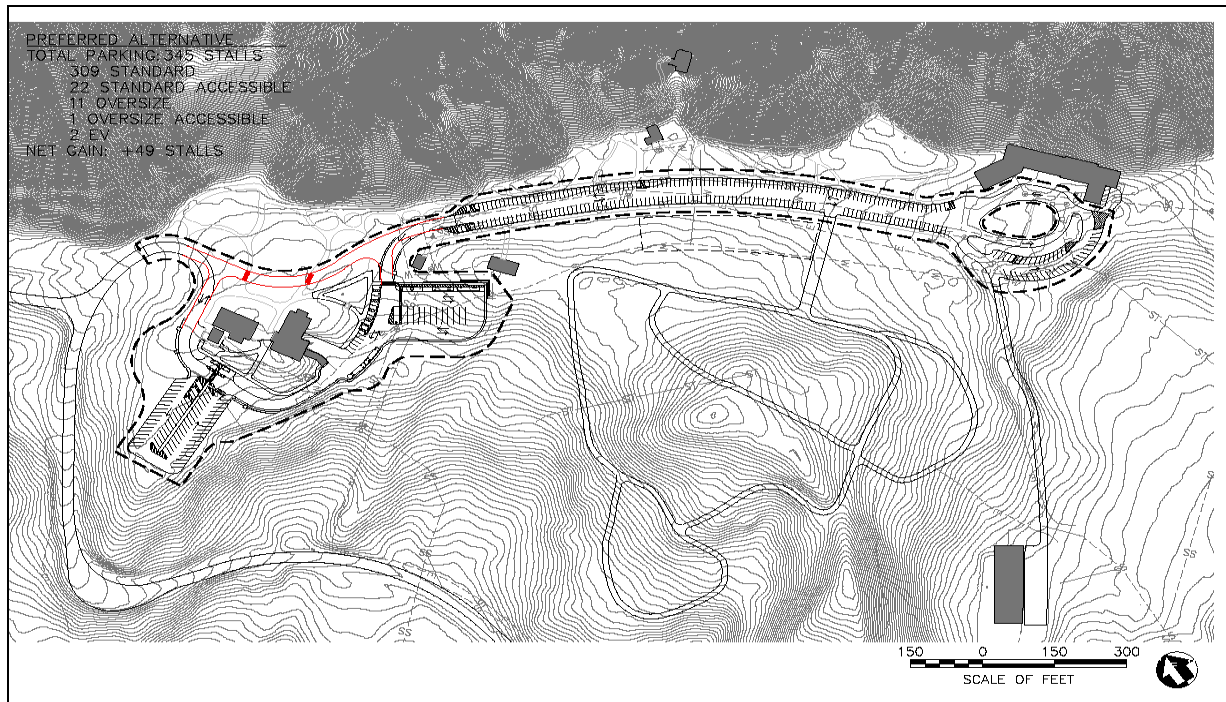


Figure 14. Drawing of the new proposed roadway (indicated by red ink) affecting the Rim Village WBP restoration planting site. Image courtesy of the Denver Service Center.



Figure 15. Location of new proposed roadway at Rim Village running through the existing WBP restoration planting site. Photo by Richard Sniezko.

Table 2. Survival rates for CRLA's six whitebark pine restoration planting sites as of 2022.

Site	2009	2010	2011	2012	2013	2014	2015	2016	*2018	2019	2020	2021	2022
2009 Horse Trail Planting (n = 192)	100.0	84.4	82.3	79.7	78.1	77.1	73.4	68.2	66.7	66.7	66.2	66.2	66.2
2009 Rim Village Planting (n = 332)	100.0	97.0	91.5	91.2	90.9	89.7	87.9	87.3	85.2	83.9	76.7	76.7	75.9
2012 Dutton Ridge Planting (n = 260)				100.0	88.8	78.5	73.8	70.0	67.7	65.4	**	63.5	62.7
2012 North Junction Planting (n = 156)				100.0	89.1	80.8	73.7	71.8	66.7	62.2	**	62.2	62.2
2016 Grouse Hill Planting (n = 240)								100.0	62.1	44.6	**	41.7	38.8
2016 Scott Bluffs Planting (n = 244)								100.0	78.7	64.8	**	63.5	63.1

*Sampling was missed in 2017 due to wildfire area closures.

**Sampling of Dutton Ridge, North Junction, Grouse Hill, and Scott Bluff was not conducted in 2020 due to limitations caused by the Covid-19 pandemic.



Figure 16. The Rim Village WBP restoration planting during the 2022 season with DGRC staff. A new proposed roadway would destroy much of the current planting site. Photos by Jen Hooke.

Controlled Pollination

Whitebark pine pollen cone phenology was monitored in 2022 from bud dormancy in late May until pollen shed in late July. Monitoring data were collected for 35 pollen cone collection candidate trees, as well as incidental data on neighboring trees. A generalized summary of these observations is presented in Table 3, although it should be noted that phenology was delayed by several weeks in 2022 due to an abnormally cool and wet spring. Using monitoring observations from 2022, a framework and pictorial reference for pollen cone phenology monitoring at CRLA was developed (Heisler and Hooke 2022). This document also contains a guide for the process of pollen cone collection.

Table 3. A generalized phenology of pollen cone development in WBP pine during the 2022 season.

Area	June Week #4	July Week #1	July Week #2	July Week #3	July Week #4
Cleetwood	Emergent	Cone Swell	Drying	Shed	Spent
Lower Dutton Ridge	Emergent	Cone Swell	Drying	Shed	Spent
North Junction	Bud Swell	Cone Swell	Drying	Shed	Spent
Discovery Point	Bud Swell	Emergent	Drying	Shed	Spent
Watchman	Undifferentiated	Bud Swell	Cone Swell	Shed	Spent
Mt. Scott Trailhead	Undifferentiated	Bud Swell	Emergent	Drying	Shed

Pollen cones were collected from five trees in 2022 (Figure 17). These trees consisted of two “A” rated trees (CL26, NJ02); two “B” rated trees (CC03, CL02), and one “F” rated tree (CC06). Collected pollen cones were transferred to the DGRC for drying, extraction, and cold storage. These collections will supplement 2023 collection efforts and provide a ready-to-use pollen source for any pollination efforts conducted in 2023.



Figure 17. Pollen cone collection in 2022. Photos by Jen Hooke.

Collection Tree Competition Release Treatment

Competition release treatments were conducted on ten high-value collection trees in August of 2022. These trees included nine confirmed rust-resistant trees, and one candidate tree currently in the rust-resistance screening process. In total, 58 trees were removed. All cut material was dispersed in a manner that prevented excessive fuel loading and maintained a natural appearance in the project areas. Treatment results for the two most heavily encroached upon trees are shown in Figure 18.



Figure 18. Before (top left, bottom left) and after (top right, bottom right) removal of WBP competitors. Photos by Scott Heisler.

Discussion

The 2022 season marked another year of implementing the Whitebark Pine Conservation Plan. While CRLA continued to experience declines in whitebark pine populations due to mortality caused by MPB, WPBR, dwarf mistletoe, and other factors, efforts to conserve the species continued. Funding assistance from the CRLA Science and Learning Center provided a dedicated technician, which allowed conducting additional monitoring work, addressing work backlogs, developing pollen cone phenology monitoring protocols, and digitizing and managing data.

Work for the WPCP in 2023 will retain emphasis on Collection Tree Monitoring and verbenone application to all Resistant and Candidate trees; sampling CRLA's seven long-term WBP monitoring plots; and monitoring the six WBP restoration outplantings. Additional work will include application of verbenone to Legacy WBP, pollen cone collection, and starting controlled pollination efforts with assistance from the DGRC. Cone collection and rust-resistance screening may occur if the cone crop allows. The process of finding new suitable, cone-bearing candidate trees can be difficult, and cone crop levels have been typically low in recent years. Additionally, planning efforts are underway to support two new research projects that will contribute to the understanding of the efficacy of WBP restoration methods at CRLA: 1) direct seeding trials; and 2) an assisted population migration study consisting of a new whitebark pine restoration planting using seedlings sourced from drier, warmer locations outside CRLA.

Recommendations for WPCP work in the 2023 season include:

- Seek funding opportunities to procure the 2024 verbenone supply.
- Continue to collaborate with the DGRC on monitoring health and status of WBP restoration outplantings.
- Identify opportunities for fuels treatments in whitebark pine habitat in conjunction with FHP and Fire Management staff.
- Work with the Rim Village Congestion planning team to ensure that whitebark pines are relocated when necessary, using tree spading methods successfully utilized in other NPS units; protected during construction activities; and considered during revegetation efforts.
- Identify new areas for potential whitebark pine restoration plantings.
- Identify new Collection trees for rust-resistance screening if cone crop allows.

Literature Cited

- Beck, J.S. and G.W. Holm. 2014. Whitebark Pine Conservation Plan. Crater Lake National Park, Crater Lake, Oregon.
- Heisler, S.E. and J.S. Hooke. 2022. Whitebark pine pollen cone phenology monitoring and collection guide. Document on file at Crater Lake National Park, Crater Lake, Oregon.
- Lanner, R.M. 1996. *Made for Each Other*. Oxford University Press, New York, New York.
- Littell, J.S., J.A. Hicke, S.L. Shafer, S.M. Capalbo, L.L. Houston, and P. Glick. 2013. Forest Ecosystems: Vegetation, Disturbance, and Economics. Pp. 110-148 in Dalton, M.M., P.W. Mote, and A.K. Snover [Eds.]. 2013. *Climate Change in the Northwest: Implications for our landscapes, waters, and communities*. Washington, D.C.: Island Press.
- Moler, E.R.V.; Reinhardt, K.; Snieszko, R.A.; Aho, K. 2022. First Report of Fungal Endophyte Communities and Non-Defensive Phytochemistry of Biocontrol-Inoculated Whitebark Pine Seedlings in a Restoration Planting. *Forests* **2022**, *13*, 824. <https://doi.org/10.3390/f13060824>
- NOAA Regional Climate Centers. 2022. *SC acis2*. Applied Climate Information System. Data retrieved October 25, 2022, from <https://scacis.rcc-acis.org/>
- Smith, S.B., D.C. Odion, and D.A. Sarr. 2011. Klamath Network Whitebark Pine Pilot Study, Crater Lake National Park, 2009. National Park Service, Klamath Network, Ashland, Oregon.
- Smith, S.B. 2017. Whitebark pine monitoring: 2016 results from Crater Lake National Park and Lassen Volcanic National Park. Natural Resource Report NPS/KLMN/NRR—2017/1484. National Park Service, Fort Collins, Colorado.
- Smith, S.B. 2018. Whitebark pine monitoring: 2017 results from Crater Lake National Park and Lassen Volcanic National Park. Natural Resource Report NPS/KLMN/NRR—2018/1710. National Park Service, Fort Collins, Colorado.
- Tomack, D.F., S.F. Arno, and R.E. Keane. 2001. The compelling case for management intervention. Pages 3-28 in: Tomack, D., S.F. Arno, and R.E. Keane, eds. *Whitebark Pine Communities: Ecology and Restoration*. Washington, D.C.: Island Press.
- Tombach, D.F., K.G. Chipman, L.M. Resler, E.K. Smith-McKenna, and C.M. Smith. 2014. Relative abundance and functional role of whitebark pine at treeline in the northern Rocky Mountains. *Arctic, Antarctic, and Alpine Research* 46(2): 407-418.
- Tombach, D.F., R.E. Keane, A.W. Schoettle, R.A. Snieszko, M.B. Jenkins, C.R. Nelson, A.D. Bower, C.R. DeMastus, E. Guiberson, J. Krakowski, M.P. Murray, E.R. Pansing, and J. Shamhart. 2022. Tamm review: Current and recommended management practices for the restoration of whitebark pine (*Pinus albicaulis* Engelm.), an imperiled high-elevation Western North American forest tree. *Forest Ecology and Management* 522(15): 119929.

U.S Fish and Wildlife Service. 2022. Endangered and Threatened Wildlife and Plants; Threatened Species Status With Section 4(d) Rule for Whitebark Pine (*Pinus albicaulis*). Federal Register 87(240): 76882-76917.

Ward, K., R. Shoal, and C. Aubry. 2006. Whitebark pine cone collection manual. USDA Forest Service, Pacific Northwest Region, Oregon and Washington.

Warwell, M.V., G.E. Rehfeldt, and N.L. Crookston. 2007. Modeling contemporary climate profiles of whitebark pine (*Pinus albicaulis*) and predicting responses to global warming. Pages 139-142 in: Proceedings of the conference on whitebark pine: a Pacific Coast perspective. Ashland, Oregon: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region.

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.

April 2023

National Park Service
U.S. Department of the Interior



[Crater Lake National Park](#)

P.O. Box 7
Crater Lake, OR 97604