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Whitebark Pine Cone Collection Manual

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Pacific Northwest Albicaulis Project

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Whitebark pine *(Pinus albicaulis)* cones, Tyee Mountain, Okanogan and Wenatchee National Forests

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Abstract

Whitebark pine is an essential component of high-elevation ecosystems in the western United States and southwestern Canada. In Oregon and Washington, whitebark pine is typically found in upper montane and subalpine habitats above 1,525 meters (5,000 feet). Whitebark pine is threatened by the non-native fungal disease white pine blister rust, attack by mountain pine beetle, and changes in forest succession resulting from fire suppression. Cone collection is a fundamental part of whitebark pine rust resistance testing, conservation, and restoration activities. There are seven distinct phases in the implementation of a whitebark pine cone collection program: conducting cone surveys, selecting collection sites, selecting individual trees, installing cone cages, harvesting the cones, and post-harvest cone handling. This manual describes these seven phases and addresses planning, budget (workforce and supplies), and implementation. Appendices include site and tree selection criteria, examples of field forms, and instructions for making one type of cone cage.

The **Pacific Northwest Albicaulis Project** of the USDA Forest Service endeavors to support the conservation and restoration of whitebark pine ecosystems in Oregon and Washington through field and laboratory studies, publications, and development of management strategies. For more information on this project, contact Carol Aubry, geneticist, caubry@fs.fed.us.

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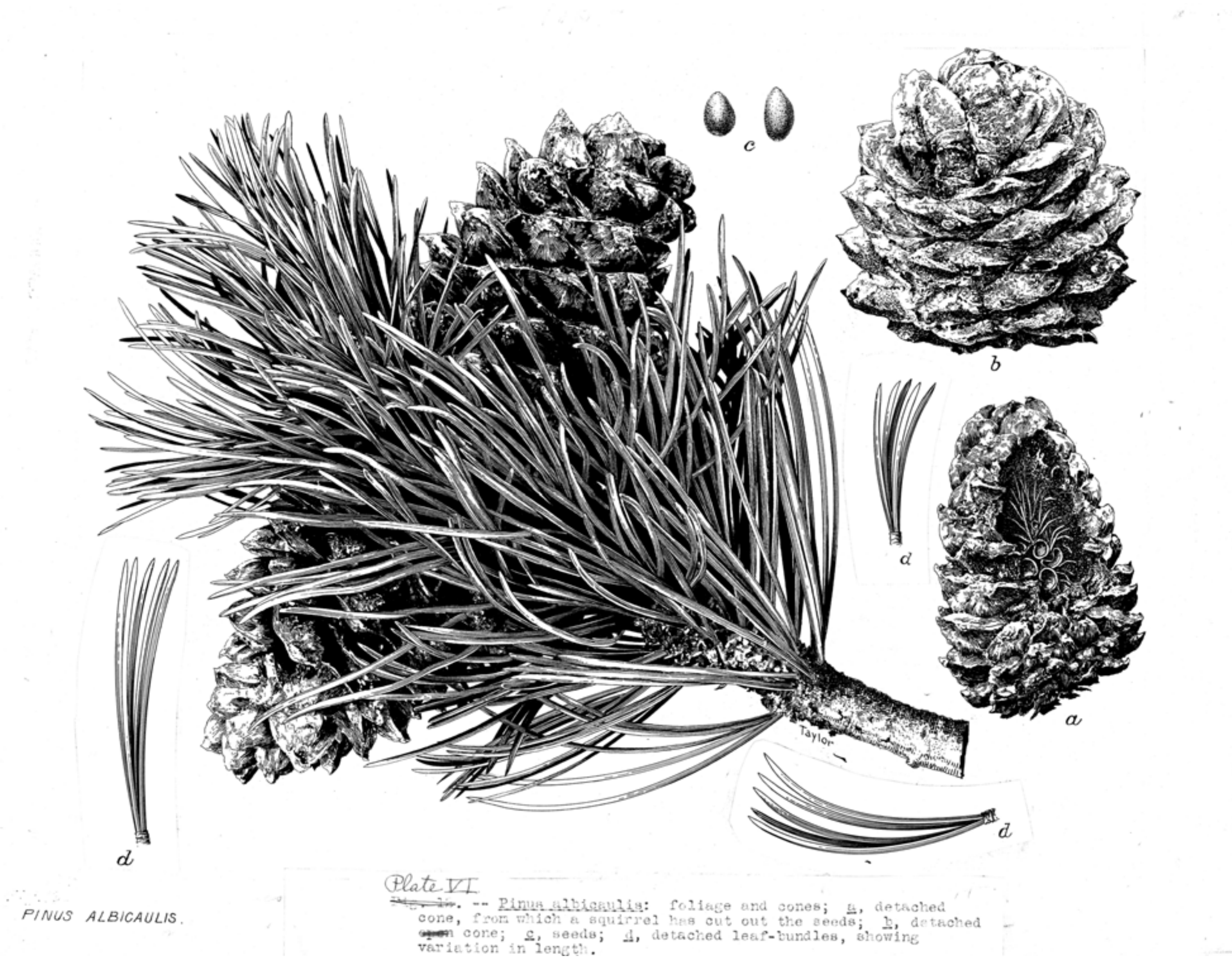

Figure 1. "*Pinus albicaulis*: foliage and cones, a. Detached cone, from which a squirrel has cut out the seeds, b. Detached cone, c. Seeds, d. Detached leaf bundles, showing variation in length"

Ink drawing by C.L. Taylor. United States Department of Agriculture Forest Service Collection, Hunt Institute for Botanical Documentation, Carnegie Mellon University, Pittsburgh, PA.

Introduction

Whitebark pine is an essential component of high-elevation ecosystems in the western United States and southwestern Canada. In Oregon and Washington, whitebark pine is typically found in upper montane and subalpine habitats above 5,000 feet, frequently being the only tree species able to thrive on harsh, dry sites. It is an important food source for wildlife and plays key roles in plant community establishment and watershed protection. One of the unique features about whitebark pine is its mutualistic relationship with an individual species of bird, the Clark's nutcracker (*Nucifraga columbiana*), on which the tree is almost completely dependent for seed dispersal (Tomback 2001). The seeds of whitebark pine are large and lack the wings associated with pines whose seeds are dispersed by wind.

Whitebark pine is threatened by the non-native fungal disease white pine blister rust (*Cronartium ribicola*), attack by mountain pine beetle (*Dendroctonus ponderosa*), and changes in forest succession resulting from fire suppression (Tomback et al. 2001). USDA Forest Service Pacific Northwest Region (Region 6, Oregon and Washington) has begun whitebark pine cone collection as part of a conservation and restoration strategy for the species in the Pacific Northwest. This manual contains recommendations for planning and implementing a whitebark pine cone collection program. The information here is based on published and unpublished material, conversations with people experienced in the many facets of whitebark pine cone collection, and our own first-hand experience planning and implementing whitebark pine cone collections on the Okanogan and Wenatchee national forests in 2005. Our objective is to provide information to Forest Service managers in Oregon and Washington who are interested in developing a whitebark pine cone collection program.

Whitebark pine reproductive biology

Cone production

Figure 2. Whitebark pine strobili and mature seed cone.

Whitebark pine cones require two years to reach maturity. The strobili (female cone flowers) (fig.2) and pollen cones (fig.3) are produced in mid-summer of the first year, and pollination occurs that same season (McCaughey and Tomback 2001). The conelets overwinter while still quite small, having acquired a size of about 3.0 cm by 2.0 cm (1.2 in by 0.8 in). The following year the cones expand in the spring, ripen through the summer, and are ready for harvest in the fall (fig.4). At maturity, cones measure 5.0 to 8.0 cm (2.0 to 3.0 in) in length and 2.0 to 5.0 cm (0.8 to 2.0 in) in width. Clark's nutcrackers, squirrels, chipmunks, and other wildlife begin harvesting the seeds in mid-summer of the second year, often before the seeds are ripe. For this reason, protecting the cones with wire mesh cages is a vital part of a whitebark pine cone collection program.

Figure 3. Whitebark pine pollen cones.

Whitebark pine is known for its masting pattern of cone production, with synchronous abundant cone production in some years ("mast years") and very little cone production in others ("fail years"). There are no data chronicling cone crop sizes over time in the Pacific Northwest, but most observers have reported variation in cone crop sizes from year to year and between locations within the same year. Observations in the field suggest that hot dry sites with open whitebark pine stands on a southwest exposure may produce larger cone crops than other sites in moderate cone crop years. This correlates with reports of larger open-grown trees producing the largest cone crops (McCaughey and Tomback 2001).

Seed yield per cone

Figure 4. Mature whitebark pine cones.

Information about seed yields per cone is helpful when identifying the number of cones to collect and thus the amount of caging material needed. The number of seeds per cone is highly variable. The number of seeds and filled seeds (seeds in which the embryos fill more than 50 percent of the embryo cavity) per cone were recorded for 100 seed lots processed between 1994 and 2001 at the Dorena Genetic Resources Center near Cottage Grove, Oregon (Berdeen, personal communication, 2005). In these data the average number of seeds per cone was 18 (range 0–42, standard deviation 11.5), and the average number of filled seeds per cone was 15 (range 0–40, standard deviation 11.5). Hutchins and Lanner (1982) empirically estimated an average number of 50.4 (+/-24.2) seeds per cone in 91 cones collected in Squaw Basin, Wyoming in 1980. Williams and Kendall (1998) reported an average of 50 seeds per cone (range 26–82) in a particularly healthy individual tree in Glacier National Park in northern Montana. To get the minimum number of fully developed seeds needed to meet a given objective, use of the more conservative average of 15 filled seeds per cone is probably wise.

Planning: objectives, budget, and timeline

Early planning is essential for the success of a whitebark pine cone collection program. To acquire sufficient supplies and schedule work crews, certain decisions will need to be made well before the field season begins, such as: the number of collection sites, the number of trees to include at each site, the number of seeds required from each tree, and whether to hire contractors or use force account crews. The availability of cones in a given year, the purpose of collecting cones, and budget considerations all play a role in making these decisions.

Objectives

The number of collection sites, as well as the number of trees to include and the number of cones to collect from each tree, will depend on the objectives of the cone collection program. Objectives include blister rust resistance testing; gene conservation; operations (replanting, site restoration, rehabilitation after fire); or the development of seedlots from select trees in a genetics program. Below are general guidelines to follow when planning to collect whitebark pine cones for these various objectives. In practice it may be challenging to meet these guidelines because of site accessibility, tree conditions, and cone production.

Collections for rust resistance testing

For blister rust resistance testing, sites that have moderate to heavy levels of white pine blister rust infection (fig.5) should be selected. Healthy trees in these areas are more likely to exhibit disease resistance (Mahalovich and Dickerson 2004).

Figure 5. Blister rust cankers on whitebark pine.

Rust resistance testing for Region 6 is done at the Dorena Genetic Resource Center, which requires a minimum of 150 seeds per tree. An additional 42 seeds per tree are needed to screen for the major gene form of resistance.

To clearly identify parentage of the seedlings included in rust resistance trials, collections for rust resistance screening must be made from individual trees and the collections must be kept separate. Because blister rust resistance is likely to be rare, it is best to collect from as many trees per site as can be accomplished with the resources at hand. Beyond collecting the minimum number of seeds per tree required for rust resistance tests, it is better to maximize the number of trees per site rather than the number of seeds per tree.

Conservation collections

Conservation collections are established to contribute to the survival and recovery of a species (Falk and Holsinger 1991). The intent is to make genetically representative collections that will be maintained in high quality seed storage and may be used for genetic studies.

Much of the genetic diversity of whitebark pine comes in the form of rare genetic variants (rare alleles) that are likely to be spread out over many populations (Jorgensen and Hamrick 1997). Because resistance to blister rust disease is likely to be rare, conserving these rare variants may be crucial to whitebark pine's ability to evolve resistance in the face of a disease which itself evolves over time (Hoff et al 1994). To capture a substantial proportion of the rare alleles found in whitebark pine, collections should be made from many trees per population and from many populations in a variety of locations (Jorgensen and Hamrick 1997).

Collections for gene conservation should be made from individual trees and the collections should be kept separate. Between 50 and 300 seeds should be collected per tree. Although nutcracker caching patterns preclude any direct association between the degree of relatedness and distance between trees (Furnier et al. 1987), collecting from widely spaced trees is recommended to reduce relatedness.

Collections from select trees

Select trees have been chosen for use in seed production or a breeding program because of their phenotypic (what can be seen and measured) superiority in one or more characteristics such as growth, form, or disease resistance (Zobel and Talbert 1984). Criteria for selecting whitebark pine stands and individual select trees within the stands are given in appendix A.

Budget: workforce and supplies

Climbing crews—Forest Service requirements

The cones of most cone-bearing whitebark pines are accessible only by climbing (or, on the rare site where it is possible and practical, the use of mechanical lifts). Each whitebark pine tree included in a cone collection program must be climbed twice: once in early summer to install cone cages, and again at the end of the summer to remove the cages and harvest the cones. Tree climbing for the USDA Forest Service requires certification and the use of equipment that meets Forest Service specifications (Davis 2005). The Dorena Genetic Resource Center offers a tree climbing certification course annually in late June. Most first-time climbers taking the course receive a preliminary certification that is contingent on climbing with a fully certified climber for one year, although some trainees receive the full climber certification at the first training. Fully certified climbers must renew their certifications every three years.

The National Tree Climbing Guide (Davis 2005) requires that there be a certified climber on the ground who can assist and perform rescue for climbers in the trees. Hence, the minimum size of a climbing crew is two certified climbers. As additional climbers are added to a crew, the time and cost per tree climbed decrease because one ground person can serve several climbers as long as visual and voice communication can be maintained at all times (Davis 2005, p.6).

Forest Service force account crews

The tree climbing training program at Dorena maintains a list of currently certified climbers in Region 6 who may be available to assist with cone collection. After cone surveys are completed and collection sites are selected, Forest Service climbers can be recruited for short-term assistance, and the work schedule can be arranged in advance. The advantages of using force account crews (Forest Service employees) are flexibility and possibly lower per-tree costs. The main disadvantage is that many certified tree climbers are firefighters or smokejumpers, and there is a risk they could be away on fire assignments during critical cone caging or collection periods.

In our experience in 2005, it took from 1½ to 2 hours for a climber to climb a tree and install up to ten cages in the upper crown, including set-up time and moving gear between trees in a stand. Removing the cages and harvesting the cones required only about half that amount of time. Our total caging, harvesting, and travel cost per tree in 2005, including salary and travel expenses, was around $165 per tree (each tree climbed twice, no ladders) using a two-person force account crew. This is in keeping with experiences of others in Region 6 who have used force account crews for whitebark pine cone collections. The 2005 whitebark pine cone crop was moderate, our sites were remote, and we tended to cage well more than our chosen minimum of 15 cones per tree. Had we caged only the minimum, climbing costs per tree would have been somewhat lower. Adding a third climber to the team would also have reduced the per-tree costs.

Where it is practical, the use of an orchard ladder to reach lower cone-bearing branches can decrease the time needed for both caging and harvesting. We used a large, plastic-coated hook on a telescoping pole to gently pull lower cone-bearing branches down to ground level. A similar pole with a hook on each end can extend the horizontal reach of a climber in the canopy, and allow the climber to have both hands free to install cages. Crater Lake National Park has developed a useful tool that incorporates a long pole and a pair of rope-operated tongs to install and remove cages from the ground (Murray, personal communication 2005). Opportunities for creative invention abound.

Contracting

Contracts need to drawn up early, often before the size of the cone crop for that year is known and the collection sites are chosen. In addition to the costs associated with contract writing and administration, it appears that contractors may be more expensive on a per-tree basis than force account crews.

Contractors in the past have charged anywhere from $67 to $145 per tree to climb a tree once, depending on site accessibility. A representative from a tree climbing company contacted in 2005 estimated they would charge $90 to $100 per tree to climb a tree once, depending on the amount of travel required and the number of trees climbed per site.

Climbing equipment

The amount of tree climbing equipment needed will depend on the number of climbers on the crew. Contractors and some force account crews will provide their own climbing equipment. If new equipment is needed for the program, full climbing gear will cost on the order of $625 to $825 per climber, and the required rescue equipment for a climbing crew will cost around $400 (2005 prices). See Davis (2005), sections 2.1 and 7.7.1, for lists of the minimum basic equipment needed for each climber and for required rescue gear.

Climbing spurs should not be used on whitebark pine trees. Spurs will damage the thin bark on these trees, and the pitch from these wounds might attract insects and rodents. To further protect the trees, it is recommended that climbers wear soft-soled shoes (with appropriate ankle support, see Davis 2005, sec.2.1) and use tree-protectors if possible to minimize damage from rope friction.

Cone cage materials and construction

Figure 6. Cone cages installed in the crown of a whitebark pine tree.

Sturdy mesh cages need to be installed on the cone-bearing branches (fig.6) to protect the developing cones from predation by Clark's nutcrackers, squirrels, and chipmunks. If collections are contracted, the forest or district usually supplies the cages. The quantity of cage construction material required will depend on the number of cages needed in a given year. There are usually two to five cones on each cone-bearing branch, so each cage will protect two to five cones. Managers in the Forest Service Northern Region and many others have used heavy duty ¼-inch hardware cloth cages to protect whitebark pine cones from wildlife (Mahalovich and Hoff 2000). In 2005 we used the lighter-weight, ⅛-inch hardware cloth variety developed by Paul Berrang and Donna Stubbs. This design is described briefly below and in detail in appendix B. The lighter mesh is easier to transport and to carry into the tree-tops, and it does less damage to the branches. While zipties, barlocks, or copper wire is required to close the heavier ¼-inch hardware cloth cages, cages made from ⅛-inch screen (also called soffit screen) can be effectively closed by folding the cage snugly against the branch by hand.

Cages made from ⅛-inch hardware cloth and from the heavier ¼-inch hardware cloth are equally effective at excluding wildlife from the cones. In 2005 not one of the 256 ⅛-inch screen cages installed at four sites on the Okanogan and Wenatchee National Forests was raided. These cages are relatively sturdy and can probably be used for many years before needing to be replaced, although the ¼-inch hardware cloth may be more durable over the long term .

In 2005, 100-foot rolls of 2-foot wide, 27-gauge, ⅛-inch galvanized hardware cloth were available online for $28 to $57 per roll (depending on the number of rolls ordered). Shipping was about $14 per roll. A roll this size contains enough material for 66 Berrang and Stubbs type cages, approximately 1 x 1-1/2 feet finished size. Additional supplies needed for constructing the cone cages are wire snips, duct tape, and sturdy leather gloves. Including materials and labor, cost per cage in 2005 was about $1.75.

Seed extraction, storage, and testing

Cones should be sent to the Dorena Genetic Resource Center for extraction, storage, and testing. Materials for shipping the cones – burlap sacks, tags for the sacks, and blank select tree registers – are available from Dorena.

Implementation

Timeline

After the objectives have been determined, there are seven distinct phases in the implementation of a whitebark pine cone collection program: conducting cone surveys, selecting collection sites, selecting individual trees, installing cone cages, harvesting the cones, and storing and delivering cones after harvest. Table 1 presents a rough timeline for these phases, and for a few important activities within them.

Table 1. Timeline for implementing whitebark pine cone collections

Month	Activity
May–June	• Conduct cone surveys. • Select collection sites. • Planning: order supplies and equipment, make cone cages, arrange and schedule work crews.
June	• Tree climber certification workshop at Dorena.
June–mid July	• Select individual trees and permanently tag them with metal tags. • Complete a selected tree register for each tree. • Install cone cages.
July–August	• Obtain burlap sacks, ties, and tags from Dorena. • Identify a suitable storage facility if cones will need to be stored for any length of time before delivery to Dorena.
Mid-September–October	• Harvest the cones. • Store cones after harvest (if necessary). • Deliver cones and select tree registers to Dorena.

Cone surveys

Because of the yearly and geographic variation in cone production, cone surveys are a vital part of selecting collection sites and planning the scope of cone collections for a given year. Cone surveys entail simply going to the potential collection sites, using binoculars to look for cones in the tree tops, and recording the observations. In theory, these immature conelets (fig.7) could be counted during the summer in the year prior to planned collections. In practice the cones are too small to be easily seen from the ground at this time. Mahalovich and Hoff (2000) suggest that snowmobiles could be used to conduct conelet surveys during the winter. Otherwise, cone surveys should be initiated as

Figure 7. First-year whitebark pine cone ("conelet").

soon as the sites are accessible in the collection year. Appendix C includes an example of a field form that can be used for cone surveys.

Identifying the collection sites

An ideal site for cone collection has several characteristics:

- It is accessible by road;
- Most of its whitebark pine trees have abundant cones (with most tree-top branches bearing several cones each); and
- Many of the trees are fairly close to the road and safely climbable.

Even more ideal is such a site with a nearby campground, fire lookout, or work center where the crew can stay overnight if more than one day will be needed to complete the caging or cone harvest work.

Selecting individual trees

Before cages can be installed, appropriate trees need to be selected (see discussion about collections for rust resistance testing, above). Criteria for selecting trees include vigor, abundance of cones, tree form, relative absence of rust and insects, distance from the other selected trees, access, and climbability. The selected trees should relatively free of rust infection or mountain pine beetle attack. The most important consideration in choosing trees for collection is safety in climbing. The tree hazards described in the National Tree Climbing Guide (Davis 2005, sec. 2.3.2) may render an otherwise suitable tree unclimbable. If resources are limited and appropriate trees are abundant, it is efficient to choose trees that have easily reachable cones. Trees that can be three-point climbed from the ground or accessed by ladders may be quicker to climb than those that require use of a rope to access the canopy. Tree selections can be made at the time of the cone surveys, or by the climbing crew when they arrive to cage cones if the crew is trained in advance to identify appropriate trees.

Whitebark pine often grows in clumps of several different stems. Because trees within the same clump are potentially closely related, only one single stem in a clump should be selected for cone collection if the purpose of the program requires known parentage, such as for gene conservation or rust resistance testing. In addition to collecting from trees that are relatively free of blister rust, collecting from trees with multiple healed or inactive blister rust cankers in a generally high infection area might increase the chances that the trees selected are resistant to blister rust.

Each tree selected should be given a unique identification number and tagged with a permanent tag. A Select Tree Register form must be completed for each tree from which cones are collected. These forms are available from the Dorena Genetic Resource Center. The area geneticist will be able to provide the unique accession numbers required on this form. Copies of the completed forms must accompany the cones to the Dorena Genetic Resource Center. For efficiency, the ground person can complete these forms while the climber/s are installing cages. Additional data that should be recorded for each tree are the number of cages installed and the number of cones caged. If a collection is being made from a tree that has already been registered as a select tree, the tree's identification number should be recorded on the cone collection tag when the cones are harvested.

Caging cones


Figure 8. Forest Service climber and tree with cages installed.

Cages should be installed as soon as possible after the cone surveys have been conducted, and ideally no later than mid July. Mahalovich and Hoff (2000) report that in northern Idaho seed predation begins as early as June, while in other parts of the Intermountain West seed harvest by wildlife doesn't begin until mid-July. They recommend that cages be installed in June and July but no later than August 1.

It is most efficient to begin caging near the top of the tree (fig.8) and work down from there, Cones are often concentrated in the top of the crown and these cones have a greater probability of having been cross-fertilized. Ideally, cages should be evenly distributed over the crown.

Cones and branches will continue to grow as the season progresses, so it's vital to leave room inside the top of the cage for the growing branch leaders. To minimize branch damage, branches should not be bent against their normal direction of growth to get them in the cage. Leather gloves and pliers make it easier to secure the cages on the branches.

Cone collection

Assessing cone maturity


Figure 9. Whitebark pine cone and seeds.

If possible, cone harvest should take place when the seeds are fully ripe (fig.9). The degree of seed maturity before collection affects seed vulnerability to handling damage as well as seed yield, seed viability, and germination percentage and longevity in storage (Burr et al. 2001). If resources permit multiple visits to cone collection sites, cone ripeness can be monitored in the weeks before collection. The recommended procedure (Burr et al. 2001) is to collect a sample of three to five cones from six trees spread throughout a site. Each cone is cut longitudinally down the center to allow inspection of the seeds. There should be six to eight filled seeds exposed on a cut face. Seeds are considered fully mature when the embryo fills 90 percent or more of the embryo cavity (Burr et al. 2001) but a 75 percent or better filled cavity yields acceptable germination rates (Mahalovich and Hoff 2000). To get the most accurate sense of cone ripeness for the individual selected trees, it is ideal to cage extra cones on each of the trees to use for assessing cone maturity.

In practice, revisiting sites and re-climbing trees to assess seed maturity will not always be possible, so cone collection timing may depend on estimates of expected cone maturity. Seed maturation rates vary with location and weather (Burr et al. 2001), so collection times will vary somewhat across the region. It is generally recommended to collect after September 1 in southern Oregon, and from mid-September to early October or even later in Washington. However, harvesting later in the season increases the risk that early snow or inclement weather will make site access impossible or create unsafe climbing conditions. Leaving the cages on over the winter is not recommended because snow and ice buildup on the cages can cause branch damage. Crew availability and the October 1 turnover of the federal fiscal year are additional considerations that may dictate the timing of cone harvest.

Collecting the cones

Climbing a tree to remove the cages and harvest the cones takes about half the time it takes to climb and install the cages. In 2005 we found it was most efficient for the climber to pick the cones directly into a burlap sack, which the climber lowered to the ground after all the cones were harvested. The cages themselves were sturdy enough to withstand being thrown from the tree and were collected by the ground person. Ripe cones are extremely pitchy, so a separate pair of gloves (or several, inexpensive and disposable if possible) is recommended for picking the cones. Pitch can quickly jam up climbing equipment, so it is vital to minimize direct contact between pitchy gloves and climbing gear. We found that cones on some trees were very easy to pick, with fairly dry stems that readily broke away from the branches. On other trees the cone stems were green, and it was necessary to pull and twist the cones in order to harvest them. This information might correlate with the relative ripeness of the seeds, so it is a good idea to record it to compare later with data about seed yield, maturity, and germination.

If individual tree collections are being made, the cones from each tree should be kept in a separate burlap sack. Two cone collection tags (available from the Bend Seed Extractory, http://fsweb.f01.r6.fs.fed.us/seedextractory/extractory.shtml) should be filled out for each burlap sack: one tag is placed inside the sack, and one is attached to the zip-tie closure on the outside. Fill the sacks no more than one-third to one-half full. All of the sacks, even those containing only a few cones, should be closed near the top to allow adequate air circulation for the cones. Again, the ground person is an efficient choice for filling out the tags and closing up the bags of cones.

Post-harvest cone handling: storage and transport

If the cones are to be stored for any length of time before being shipped to Dorena, appropriate storage conditions are essential. The sacks of cones should be kept in a humid but well-ventilated cooler (warmer than 2 degrees C (35 degrees F)) to allow after-ripening. If a cooler is not available, the sacks should be stored in a cool, rodent-proof place on wire racks or shelves, with no direct sunlight and plenty of air circulation. If access by rodents is unavoidable, the cones can be temporarily placed back into cages for the duration of the storage period. To facilitate air circulation the sacks (or cages) should be well spaced and turned over daily.

It is possible to use commercial carriers to ship the cones, but most collection programs deliver the cones to Dorena themselves. As with cone storage, the cones need to remain dry and cool and to have adequate circulation during transport.

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Figure 10. Clark's nutcracker (*Nucifraga columbiana*) – the ultimate whitebark pine cone collector.

Appendix A: Whitebark pine select tree criteria

Stand-Level Criteria

- Vigorous and representative of the species
- Habitat type where species normally occurs
- Provide a broad sample of both the geography and range of elevations
- Overall composition has a high proportion of living or dead whitebark pine, well represented throughout the stand
- Uniformly and heavily infected with blister rust (10 or more cankers per tree on the average)
- Confirmed blister rust infection of 90 percent or higher in uniform stands
- Stands with 50–90 percent rust infection, limit selected trees to no more than five cankers

Individual-Tree-Level Criteria

- Dominant or co-dominant trees
- Minimum of 100* m between selected trees to avoid relatedness
- Free of insects and diseases
- Have a history or the potential to bear cones
- Be within 100 to 200 m from the nearest road or trail
- No more than three of the best candidates in any given stand
- No squirrel cache cone collections

* Spacing between plus trees (300 ft [100 m]) differs from spacing requirements for operational cone collections (200 ft [67 m]).

Source: Adapted from Mahalovich and Dickerson 2004, p.184.

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Appendix B: How to make a Stubbs & Berrang model cone cage

Step 1. Materials needed
- 1/8-in galvanized hardware cloth, in a 2-ft-wide roll.
- Metal cutters, duct tape, and leather gloves.

Step 2. First fold
- Cut out a piece of hardware cloth that is 1½ ft. by 2 ft.
- Fold the top down to the bottom so that the doubled piece measures 1½ ft by 1 ft.

Step 3. Closing the long side
- Fold both layers of the open side that is 1½ ft. long **twice**. Try to make each fold no wider than ½ in.

Step 4. Closing the top
- Fold both layers at one of the 1-ft. ends twice. This seals the top of the cage.

Step 5. Basic cage…
- The structure of the cage is now complete.

Step 6. Tape to protect the branches
- Tear two pieces of duct tape ~10 in. long. Tape around opening of cage, centering the tape on the corners. This helps reduce the amount of scraping on the branch.

Step 7. Opening and installing cage
- Open cage by pushing near the upper corners and put cage around the branch.
- Allow room at the top for new growth.

Step 8. Securing cage on branch
- Press the taped edges of the cage closed around the branch.
- Fold the newly formed corners down twice.

Step 9. Installation complete
- The cage is now firmly secured on the branch. (Pliers can be helpful for the double "origami-fold" on the corners.)

Step 10. Cone cages in action.

Appendix B photo credits:
Bryson Bristol, photos 1 through 9
Robin Shoal, photo 10

(The authors thank *Pseudotsuga menzeisii* for standing in for *Pinus albicaulis* in photos 7, 8, and 9.)

Appendix C: Sample whitebark pine cone survey data sheet

Date_______________________________

Forest____ Ranger District ____________________________

Site Name_______________________________________ Location T_______ R_______ S_______ Q_____

Surveyors____ Driving time from Ranger Station____________

Whitebark pine is **dense** or **sparse** (circle one). Whitebark pine stand is **mixed** or **pure** (circle one).

INDIVIDUAL TREE DATA: Complete this table for 15 trees, following the Individual-tree-level Selection criteria. If it is not possible to adhere to the criteria, select 15 trees throughout the site and record the survey results. **There is no need to mark these trees.** This table is only to quantify observations.

Individual-tree-level Selection Criteria[1]:

1. Relatively free of blister rust compared to infection level in the stand as a whole
2. Dominant or co-dominant trees
3. Far enough apart to be unrelated; there should be a minimum of 300 ft (100 m) between trees
4. Free of insects (mountain pine beetle) and diseases other than blister rust
5. At least 50 second-year cones. (Count only cones that will ripen this summer. Do not count remnants of mature cones from previous years.)

[1]Adapted from 'Plus Tree Selection Criteria' by M. F. Mahalovich, USFS, Moscow, Idaho, 2002.

Tree	Approx. number of 2nd-year cones (minimum 50)	Presence of pollen catkins (yes or no)	Number of blister rust cankers 0 = none 1 = 1-5 2 = 6-25 3 = 26-75 4 = > 75	Is this tree at least 300 feet from other candidate trees (yes or no)?	Distance from road (feet)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

OVERALL CONE PRODUCTION: Size of area covered to find 15 candidate trees___________________

Additional area with good cone production____

Approx. number of mature cone-bearing trees____

Estimated average number cones per mature tree (circle one): **0** **1–25** **26–50** **51–100** **>100**

CLARK'S NUTCRACKER PRESENT? **Yes** **No** If yes, notes________________________________

____

DETAILED DIRECTIONS TO STAND____

____

____

____

____

STAND DESCRIPTION (other tree species present, slope, aspect, etc.) ____________________________

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FEASABILITY OF CONE COLLECTION: include rough estimate of proportion of cones that can be reached by hand from the ground; feasibility of using orchard ladders to access cones; general climbability of cone-bearing trees in the stand (whether most cone-bearing trees can be climbed from the ground or will require tree-climbing ladders for access to the crown).

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ADDITIONAL OBSERVATIONS

Appendix D: Sample whitebark pine cone caging & harvest data sheet

Year______________________

Forest____ Ranger District _________________________

Site Name______________________________ Location T_______R_______S_______Q__________

Crew: Caging____

Crew: Harvesting____

Use back of sheet to record select tree GPS coordinates, directions to site, and additional notes.

	CAGING					HARVESTING		
Select tree no.[1]	Climbing methods used	Date cages installed	No. of cages installed	No. of cones caged	Time required to install cages (hours)	Date of cone harvest	Time required to harvest (hours)	Ease of cone harvest [2]

1. Unique tree ID that will be recorded on the permanent metal tree tag and on the paper tag that accompanies that tree's cones to Dorena.
2. Ease of harvest: **E** = easy–cones come off branches easily; **M** = moderate–cones require some tugging; **D** = difficult–cone stems are green and require pulling and twisting to harvest.

Coordinates and relocation information for select trees

Projection________________ **Datum**_____________ (R6 standard is Albers, NAD1983)

Select tree no.	Easting	Northing	Elevation	Relocation info [3]

3. i.e., tree no. ____________ is *xxx* meters at *xxx* degrees bearing from previous select tree or from an obvious landmark.

Directions to site:

Additional notes: