BENEFICIAL MANAGEMENT PRACTICES FOR WHITEBARK AND LIMBER PINE

Crown Managers Partnership – High Five working group, Loss mitigation and best practices committee

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Contents

1.0 Purpose and Scope

This document summarizes guidance on best practices when planning projects that may impact habitat and/or individuals of whitebark pine and limber pine. This is intended to apply to phases of industrial projects and activities, as well as conservation and management planning and activities within the entire species' range, but focused initially on the Crown of the Continent. It is not specifically intended to guide applications outside the species' range, such as assisted migration projects, that would best be addressed by a project-specific scientific literature review and risk assessment.

The aim of this document is to provide a consistent set of practices based on current information, published studies, and expert opinion. Regional differences in ecosystems and associated species cohorts, disturbance regimes, and other factors are acknowledged, and where available further information is provided. New studies are constantly being undertaken so this document represents a one-time snapshot.

For specific legislation and regulations that may apply to a given project or activity, it is imperative to refer to applicable sources for that particular jurisdiction. Because the Crown of the Continent area overlaps with numerous jurisdictions and levels of government and non-governmental authority, and because the legal landscape is constantly being revised, a comprehensive list will not be provided here. It is recommended that a competent professional with expertise in applicable legislation be involved from the early stages of planning to ensure awareness of and compliance with all applicable legislation.

2.0 Whitebark Pine and Limber Pine in the Crown of the Continent

2.1 Value and Status of High-Five Species

Jurisdiction	Whitebark Pine	Limber Pine
USA	pending decision 2019	NA
Canada	endangered (2012)	pending evaluation – recommended endangered (2014)
Wyoming (BLM lands)	Sensitive Species (2010)	Sensitive Species (2010)
British Columbia	blue listed (vulnerable) (2009)	red listed (2014)
Alberta	endangered (2008)	endangered (2008)
Global (IUCN)	red listed (2013)	least concern (1998)

Formal protection for whitebark pine under the Endangered Species Act (ESA) was declined by U.S. Fish and Wildlife Service in 2011 in deference to other higher priority listings; but the species is currently considered a "redlist" species by the grassroots International Union for Conservation of Nature[1]. Both

[1] http://www.iucnredlist.org/

whitebark and limber pines are on the Sensitive Species List for public lands in Wyoming by the US Department of Interior Bureau of Land Management. Sensitive species designation provides consideration of habitat and conservation objectives when executing land management decisions to preclude the need for listing under the federal ESA. Whitebark pine is Endangered in Canada, it is Blue-listed (special concern) in British Columbia, and was designated as "warranted but precluded" in the USA under the Endangered Species Act. Limber pine is Red-listed and described as "highly vulnerable" in British Columbia, and was designated by the Committee for the Status of Endangered Wildlife in Canada (COSEWIC) as Endangered but is still pending review and has not yet been formally listed under the Species at Risk Act.

These high elevation pines are keystone components of their respective ecosystems, meaning that when they are impacted, the unique ecosystems of which they are a part can lose core functions such as wildlife habitat, snowmelt moderation of headwater streams, slope stabilization, and upper and lower treeline community structural drivers. Because they both grow and mature very slowly, loss of a mature cone bearing tree can take up to a century to replace. These impacts are long term and where possible should be avoided.

The main immediate threat to both species in the Crown of the Continent is white pine blister rust. This introduced fungal disease infects needles, travels down twigs to the main stem, where it eventually kills the tree. In some regions over 95% of these endangered pine trees have rust, and over 75% of mature trees have died; most regions of the Crown have at least some infection, and rates are generally over 50%, with correspondingly high mortality rates. Decades of research and concerted work in the USA and Canada has identified trees that are resistant or tolerant to this disease. Their seedlings help ecosystems recover naturally to some degree, but without management intervention studies have shown that ecological tipping points due to rust, beetles, and other threats convert these stands to other forest types, losing their unique composition, structure, and function. Protecting and propagating these trees, and using their seeds for active restoration programs are essential to implementing existing restoration and recovery plans. These disease resistant trees are very rare, between 1 in 100 and 1 in 1000. The loss of even one of these high value trees can impede recovery and ecosystem sustainability.

Mountain pine beetle is also a serious threat, causing significant mortality in the mid-1980s and the most recent outbreak during the 2000s-2010s. The beetle targets mature trees, which are the most valuable cone bearing individuals, and the best seed sources of disease resistant seedlings. In less severe outbreaks, individual trees can be protected with pheromones such as Verbenone, which reduces beetle attack and mortality by over 50%. However, in severe epidemics, landscape management is a more effective tool, and can also be used to alter the distribution of age classes and species to reduce vulnerability to future beetle attacks. Mountain pine beetle outbreaks are expected to get more severe and possibly more frequent as minimum temperatures increase due to climate change – brood success is higher, overwinter survival is higher, life cycles are faster, and trees that are drought stressed due to lower snowpacks and prolonged growing season drought are more vulnerable to attack.

2.2 Potential Impacts to Whitebark Pine and Limber Pine

Table 1. Potential impacts to high elevation pines or their critical habitat by project-related activities.

Activity	Potential impacts (direct and indirect)
PROJECT ASSESSMENT PHASE	
Access for geotechnical and/or other surveys, helipads	• Loss or damage to trees and regeneration for roads, trails, seismic lines impacts habitat quality and wildlife suitability • Seed source impact: loss of cone-bearing and/or non-terminally infected mature trees • Regeneration impact: removal, replacement, or damage to suitable microsites
PROJECT CONSTRUCTION PHASE	
Linear disturbances: access roads, trails, power corridors and rights-of-way	• Loss or damage to trees and regeneration for roads, trails, seismic lines impacts habitat quality and wildlife suitability • Increase of risk for invasive plants to degrade habitat quality • Seed source impact: loss of cone-bearing and/or non-terminally infected mature trees • Regeneration impact: removal, replacement, or damage to suitable microsites
Area clearing for infrastructure	• Direct habitat loss and loss of individuals impacts habitat quality and wildlife suitability • Increased use of local area degrades adjacent habitat • Increased disturbance and use by humans reduces likelihood of local nutcracker caching resulting in less regeneration • Increased disturbance and use by humans reduces use by dependent / related wildlife (e.g. bears), decreasing habitat value • Removal of adjacent Douglas-fir stands which provide important ancillary Clark's nutcracker habitat decreases regeneration of whitebark pine
Project area maintenance (vegetation control): includes ski run glading	• Loss or damage to trees and regeneration impacts habitat quality and wildlife suitability *Note: competing vegetation may be manually removed without damaging whitebark or limber pine.*
PROJECT DECOMMISSIONING PHASE	
Reclamation activities	• Increased mineral soil exposure increases risk for invasive plants to degrade habitat quality • Inappropriate fire management such as deliberate high-intensity and/or high severity (stand-replacing) burns may kill or damage cone-bearing and/or non-terminally infected mature trees or regeneration • Severe fires may extensively kill soil stabilizing vegetation and increase soil erosion, and increase noxious weed recruitment *Note: Low-intensity and/or targeted burns may be achievable without damaging key attributes*

Planting/revegetation	• Seed source must be well adapted to the site (local or regional) • Deliberately planting seedlings of any competing tree species within critical habitat advances forest succession at the direct expense of whitebark pine regeneration, and increases competition which directly and cumulatively increases mortality of mature whitebark pine • Long term monitoring is needed to gauge success after planting whitebark and limber pine to determine the degree to which habitat quality can be restored
GENERAL LAND/HABITAT USE	
	• Inappropriate levels of livestock grazing may directly or cumulatively damage habitat and regeneration by impairing seed and seedling viability *Note: Some grazing may occur in stands where average whitebark or limber pine is taller than 2 m without net damage, but seedlings should be protected. Avoid regenerating or recovering habitats where average pine height is <2 m*

3.0 Guiding Principle: Mitigation Hierarchy

The best practice is to follow the Mitigation Hierarchy. Ecosystems are complex systems, and to fully restore the functions and capacity of key components after disturbance may be difficult or impossible during some project or post-project monitoring periods, so avoiding and minimizing disturbances to key ecological values are preferred through prudent project design and planning.

Proponents should (in the following order) to: **Avoid, Minimize, Restore, Offset / Compensate** impacts. After proponents have demonstrated avoidance is not possible or practicable, minimizing impacts should be undertaken, and so on down the hierarchy.

1. Avoidance – The primary and preferred response is to avoid impacts to five-needle pines and their habitat

2. Minimization – Where avoidance is not possible, proponents are expected to minimize impacts on 5 needle pines and their habitat

3. Mitigation / Restoration – Where avoidance is not possible and minimization still results in impacts, habitat restoration of the population is preferred

4. Offset / Compensation – As a last resort, and where avoidance and minimization efforts are not feasible or prove ineffective, use off-site offsets and/or compensation to mitigate remaining impacts

3.1 Baseline data collection

Proponents must exercise due diligence by seeking out existing location records, study results, habitat suitability/capability models, and information on high value stands or individuals as part of a preliminary review. The scale of mapping and interpretation must be relevant and appropriate when considering the scale and methods of data collection for each data source. When evaluating potential impacts to habitat and individuals, models and available data should be supplemented by a site visit to confirm model accuracy for a particular area and to identify features that may not be captured in existing data sets and models.

Data must be collected in the proposed project area to quantify the resource and any potential impacts. Data must be collected in accordance with accepted standards and results provided in a format compatible with the relevant reporting and authorizing agency requirements (e.g. stems per hectare and/or basal area of live and dead mature trees, saplings, seedlings, geographic location and characteristics of plus trees, percent infection of blister rust and mountain pine beetle in the stand, cone production per hectare, wildlife occupancy and use, habitat quality stratification by key attributes).

A qualified professional with experience in five needle pine assessments is highly recommended for this work. Standardized protocols already in place should be used such as the Whitebark Pine Ecosystem Foundation's Methods for surveying and monitoring whitebark pine for blister rust infection and damage, Breeding Bird Surveys, Resource Information Standards Committee protocols, or other published methodology.

Different jurisdictions may have their own standards proponents are requested to follow. For example, Alberta has established protocols following the United States Department of Agriculture Forest Service

Intermountain Region lead and issues unique identities, tree tags, and records the spatial locations of all plus trees in its provincial program using a standardized format, and sends seeds from those trees for disease resistance screening to a recognized facility. United States National Forests or Bureau of Land Management have databases for compiling similar records and support screening programs. It is essential to check with the land management agency for what procedures to follow in your area.

- At the minimum, proponents are to conduct a **survey of the project footprint area** identifying the number of whitebark and/or limber pine trees impacted in each of the following classes: trees (>1.3 m tall), saplings (0.5-1.3 m tall), seedlings (<0.50 m tall), and identify how many would be impacted by the project. The stand must be surveyed by a professional with blister rust identification experience
- **Trees that appear to be disease resistant** are to be clearly identified and assessed following agency protocols. Submit data to the agency. All accessible seeds should be collected from each candidate tree following seed collection handling guidelines in this document, and samples submitted to the appropriate agency for gene conservation and for blister rust resistance screening; the remainder can be stored properly and used for reclamation. All measures should be taken to avoid impacting these trees.
- Contact the appropriate land management agency to determine whether a **long term health monitoring plot or transect** exists within 1 km of the site. If yes, the agency will confirm if a current assessment is needed and the proponent should retain an experienced professional to do this. If not, proponents should retain an experienced contractor to establish a health transect in representative habitat in the project area following the Whitebark Pine Ecosystem Foundation's methodology, collect and submit all data in a format agreeable to the agency to add to their existing data sets.

References

Tomback, D. F., R. E. Keane, W. W. McCaughey, and C. M. Smith. 2005. Methods for surveying and monitoring whitebark pine for blister rust infection and damage. Whitebark Pine Ecosystem Foundation, Missoula, Montana. 30 pp. http://whitebarkfound.org/wp-content/uploads/2013/07/Methods-for-Surveying-and-Monitoring-Whitebark-Pine-for-Blister-Rust.pdf

3.2 Avoidance

Avoidance is the highest priority. Proponents must demonstrate they have made a concerted effort to avoid impacts to five-needle pine habitats and individuals in their application. The onus is on the Proponent to demonstrate a) avoidance of critical habitat and individuals, and b) preservation of habitat functional integrity. Evidence of avoidance must include:

- Options considered for relocating the activity
- Alternative activities considered in the proposed area
- Modifications considered to the proposed activity
- Comparative analysis of alternative options to the proposed activity
- When there is a need to balance avoidance with having the smallest footprint on the landscape, the rationale for this balance must be documented

Candidate rust-resistant trees ("plus trees") and trees tested and confirmed to have some degree of disease resistance or tolerance are the least common and highest value; they therefore require the greatest effort to avoid. Proponents must provide a comparative analysis of each alternative option to

the proposed activity, including at least one option that will avoid the plus tree entirely. The comparative analysis must provide rationale regarding the chosen approach for each of the options considered.

3.3 Minimization

Minimization refers to "reducing negative impacts on five-needle pine habitats and individuals to the smallest practicable degree during the planning, design, construction, and operational stages of development, and when conducting activities that may harm wetland" (*sensu* Alberta Wetland Policy 2013). Minimization is the second priority after a proponent has demonstrated that avoidance is not possible. The onus is on the Proponent to demonstrate a) that impacts on five-needle pines and their habitat (where different from avoidance), including indirect impacts, have been minimized and b) relative habitat value has been preserved. Evidence of minimization must include:

- Alternative activities considered in the proposed area
- Modifications considered to the proposed activity
- Comparative analysis of alternative options to the proposed activity
- Explicit commitment to reclaim the area back to functioning habitat, post-operations

Candidate rust-resistant trees ("plus trees") and trees tested and confirmed to have some degree of disease resistance or tolerance are the least common and highest value; they therefore require the greatest effort to minimize impacts. Proponents must provide a comparative analysis of each alternative option to the proposed activity, identifying how, to the greatest extent possible, the activity minimizes permanent loss of and temporary impact to plus trees. Proponents must provide a rationale regarding their choice for each of the options considered.

Mature cone-bearing trees, even if they are not plus trees, are still of substantially higher value than seedlings or saplings because of their essential habitat functions. The slow growth and maturation of these species require 40 to 50 years on average for trees to reach cone-bearing age, and 80 to 100 years for trees to begin produce reliable cone crops. Damage or removal of each tree takes many decades to replace its impact.

Minimization Proposal

Proponents must submit an impact Minimization Rationale, or other document deemed appropriate and acceptable to the regulatory body (e.g. forestry plans, Environmental Assessment Office), as part of their application. The proposal must include:

- Documentation of all options considered to minimize impacts on five-needle pine ecosystems, including modifications to the activity, design, or location
- Commitment to apply best science, technology and ecological principles
- Minimization techniques proposed to maintain natural conditions and functions of existing five-needle pine ecosystems
- Commitment to follow any available minimization guidance on Best Management Practices or Standard Operating Procedures for that activity
- Location or relocation of construction and maintenance activities to prevent or minimize impacts to five-needle pine -dependent species

3.4 Restoration

Where restoration is required, any permanent loss of five needle pine habitat area that will not be reclaimed back to the same is subject to replacement. Permanent loss is defined as "the permanent

elimination of limber or whitebark pine habitat value resulting from a reduction/removal of limber or whitebark pine habitat area" (sensu Alberta Wetland Policy, 2013). Success of mitigation or restoration activities is determined by monitoring against pre-disturbance benchmarks and if not successful within the approved time period, additional mitigation is necessary to meet those benchmarks.

To the extent possible, habitat replacement must occur in the following geographic order of priority:

1. Within the same population as the site of permanent habitat loss

If there are no restoration options available within the same population, replacement priority should be:

2. Within the same mountain range or landscape element (e.g. foothills)
3. Within the same Natural Subregion or equivalent division (Biogeoclimatic subzone)
4. In areas of high habitat loss within the jurisdiction

3.4.1 Restoration – same population

Proponents can fulfill their replacement obligations through any combination of the following options:

- The proponent restores, enhances or constructs limber or whitebark pine habitat, either in advance of- or soon after- permanent losses have been incurred.
- The replacement matrix (Table 2) depicts individual tree replacement ratios on the basis of relative value that is lost versus what is replaced, taking planting stress mortality and the long time to reproduction into account. The opportunity cost of the primary habitat value provided by a mature tree is valued higher than replacing a juvenile individual. The impact of removing a plus tree is weighted highest. All seedlings are to be produced from regionally adapted selected plus tree sources.

Table 2. Replacement matrix for whitebark and limber pine impacts to individuals

	Trees impacted		
Mitigation guideline	seedling or sapling	mature tree (cone bearing)	plus tree
Replacement no. of seedlings from selected plus trees	20	100	200

- If available, collect seeds from plus trees as feasible in the region, document those trees and collections, and either make the seeds available for restoration, or produce seedlings for restoration. This functions as a reclamation bank. Numbers of plus trees, seeds, seedlings to be determined by the authorizing agency.
- If available, collect grafts and pollen from plus trees following the guidelines in this document and submit to the appropriate regional gene conservation and/or forest health agency with applicable documentation to include in a whitebark pine or limber pine breeding program. Enquire first if sufficient rootstock is available or may be purchased before taking grafts.
- Send seeds from as many plus trees as feasible in the region for disease resistance screening at an approved facility. Numbers of plus trees to be determined by the authorizing agency.
- Erect an interpretive sign and demonstration planting to explain the value of whitebark and/or limber pine habitats and restoration initiatives. Enquire with local agencies - suitable sign templates may be available.

3.4.2 Restoration – different population

Where some localized impact cannot be avoided, and suitable habitat is not available in the immediate vicinity, use the following mitigation options. This may apply where the project footprint is planned for expansion, or where an entire stand of trees is affected and there is no other suitable habitat on site, or where the proponent is amenable additional measures (e.g. as part of certification or other project commitments). Experienced professionals must be used for data collection.

- The proponent restores, enhances or constructs limber or whitebark pine habitat, either in advance of- or soon after- permanent losses have been incurred.
- Proponents are to conduct a survey of the offset area identifying the number of whitebark and/or limber pine trees impacted in each of the following classes: trees (>1.3 m tall), saplings (0.5-1.3 m tall), seedlings (<0.50 m tall)
- Trees that appear to be disease resistant are to be clearly identified and assessed following agency protocols. Submit data to the agency. All accessible seeds should be collected from each candidate tree following seed collection handling guidelines in this document, and samples submitted to the appropriate agency for gene conservation and for blister rust resistance screening; the remainder can be stored properly and used for reclamation. All measures should be taken to avoid impacting these trees.
- Contact the appropriate land management agency to determine whether a long term health monitoring plot or transect exists within 1 km of the reclamation site. If yes, the agency will confirm if a current assessment is needed and the proponent should retain an experienced professional to do this. If not, proponents should retain an experienced contractor to establish a health transect in representative habitat in the project area following the Whitebark Pine Ecosystem Foundation's methodology, collect and submit all data in a format agreeable to the agency to add to their existing data sets.
- The replacement matrix (Table 2) depicts individual tree replacement ratios on the basis of relative value that is lost versus what is replaced, taking planting stress mortality and the long time to reproduction into account. The opportunity cost of the primary habitat value provided by a mature tree is valued higher than replacing a juvenile individual. The impact of removing a plus tree is

weighted highest. All seedlings are to be produced from regionally adapted selected plus tree sources.

- If available, collect seeds from plus trees as feasible in the region, document those trees and collections, and either make the seeds available for restoration, or produce seedlings for restoration. This functions as a reclamation bank. Numbers of plus trees, seeds, seedlings to be determined by the authorizing agency.
- If available, collect grafts and pollen from plus trees following the guidelines in this document and submit to the appropriate regional gene conservation and/or forest health agency with applicable documentation to include in a whitebark pine or limber pine breeding program. Enquire first if sufficient rootstock is available or may be purchased before taking grafts.
- Send seeds from as many plus trees as feasible in the region for disease resistance screening at an approved facility. Numbers of plus trees to be determined by the authorizing agency.
- Erect an interpretive sign and demonstration planting to explain the value of whitebark and/or limber pine habitats and restoration initiatives. Enquire with local agencies - suitable sign templates may be available.

3.5 Offset / Compensation

This option is to be only undertaken after none of the above alternatives have proven feasible. The proponent must demonstrate in their proposal all of the steps taken to avoid, minimize, and mitigate both on site and off site before considering an offset or compensation approach.

- If available regionally as an option, make an in lieu payment to an agency that will undertake conservation and/or reclamation work for whitebark and limber pine habitat. This can entail direct purchase of habitat, payment to conduct surveys, covering costs of seed collection, disease screening, seedling production, restoration planting, support of applied research, and/or interpretive programs. Value and options to be determined by the appropriate agency.
- Erect an interpretive sign and demonstration planting to explain the value of whitebark and/or limber pine habitats and restoration initiatives. Enquire with local agencies - suitable sign templates may be available.

4.0 Beneficial Management Practices

The following summarizes currently available guidance on best practices for various activities associated with whitebark pine and limber pine management and restoration. There may be a range of targets depending on objective, region, ecosystem type, and other factors so it is a good practice to check the supporting material against your management regime. Check the website of the Whitebark Pine Ecosystem Foundation[2] and other resources for the most current information.

4.1 Blister rust identification

You absolutely need a good set of binoculars with a good lens diameter for light, and some patience, to look for rust. Two people examining each tree for at least several minutes each are more likely to notice rust symptoms than one person. Binocular specifications are in *Methods for Surveying and Monitoring Whitebark Pine for Blister Rust Infection and Damage*.

If you are not certain about rust (e.g. lots of lichen covering branches, dense crown, or very rough bark) then record uncertain instead of inaccurately recording yes or no to rust.

A great resource with photos is Hoff's 1992 publication *How to Recognize Blister Rust Infection on Whitebark Pine*.

If active sporulating cankers are not visible, if at least 3 of the 5 secondary symptoms are visible then rust should be considered present on a tree. Record which secondary symptoms are on each tree. A good summary and photos of the secondary symptoms is in section 3.4.4.7 of the Interagency *Whitebark Pine Monitoring Protocol for the Greater Yellowstone Ecosystem*. Secondary indicators are (GYWPMWG 2011):

- Flagging: When cankers girdle a branch, the branch dies and becomes a "flag."
- Swelling: The occurrence of a canker often causes swelling on the branch or trunk (which may be yellow-orange in color). This is amplified when rubbed with water.
- Roughened Bark: The occurrence of a canker often causes roughened bark.
- Rodent chewing (stripped bark): The high sugar content associated with cankers makes them attractive to rodents and insects. Thus chewing of these sweet tissues is often an indicator of blister rust.
- Oozing Pitch: Pitch is often associated with the margin of a canker and may run down the branch or trunk.

References

Tomback, D. F., R. E. Keane, W. W. McCaughey, and C. M. Smith. 2005. Methods for surveying and monitoring whitebark pine for blister rust infection and damage. Whitebark Pine Ecosystem Foundation, Missoula, Montana. 30 pp. http://whitebarkfound.org/wp-content/uploads/2013/07/Methods-for-Surveying-and-Monitoring-Whitebark-Pine-for-Blister-Rust.pdf

Hoff, R. J. 1992. How to recognize blister rust infection on whitebark pine. USDA Forest Service, Intermountain Research Station, Research Note INT-406, Ogden, Utah. 7 pp. https://www.fs.fed.us/rm/pubs_int/int_rn406.pdf

[2] http://whitebarkfound.org/

Greater Yellowstone Whitebark Pine Monitoring Working Group (GYWPMWG). 2011. Interagency whitebark pine monitoring protocol for the Greater Yellowstone Ecosystem, version 1.1. Greater Yellowstone Coordinating Committee, Bozeman, Montana http://whitebarkfound.org/wp-content/uploads/2013/10/GYE_Whitebark_Monitoring_Protocol_June_2011_Version1_1.pdf

4.2 Data collection and documentation

Whichever method you decide to use, check if there is a standardized data collection format and database available that you can add your data to. This enables cross-jurisdictional data sharing and comparison, which adds significant utility and power to your data set.

- In the field, make sure all data is filled out completely and correctly before leaving the field site. It is expensive and may be impossible to return to some sites, and after a day or two it is impossible to accurately remember details of trees or plots.
- Take photos of plot cards and any reference notes immediately before each photo so you know what the photo is describing, and manage your data and photos every day after returning from the field to avoid accidentally losing, deleting, or forgetting files and information. If using an app to collect field data that allows attachments this can save a lot of time managing files.
- Document all relevant information and use as many standardized, quantitative variables as possible.
- Include field crew names so that if any questions arise they can clarify.
- Ensure dates and locations are fully filled out.
- Notes can be extremely helpful so take lots of notes, and always check notes when reviewing data.
- The crew should take photos of any potential disease or insect signs that they are not certain of and submit them for expert identification. This is the best way to ensure that emerging insect and disease issues are identified promptly, and that important health data is accurately recorded.

4.3 Species and habitat inventory

4.3.1 Critical habitat identification – landscape level

This guidance is from the draft *Recovery Strategy for Whitebark Pine (*Pinus albicaulis*) in Canada* [pending publication].

Survey area for whitebark pine in order to determine location and configuration of individuals on the landscape.

1. Identify high-density stands (≥2 m^2/ha basal area of whitebark pine and/or limber pine within landscape inventory polygons). Within these landscape inventory polygons, avoid removal of whitebark pine and/or limber pine that are not terminally infected or that are cone-producing), and/or any activities that result in damage or destruction of the soil layer to the extent that microsites for seeds and/or seedlings, subsurface roots and ectomycorrhizal associations are destroyed.
2. Identify additional regeneration and recovery habitat
    a. In the 2 km area surrounding high-density stands, identify open parkland and natural forest openings ≥0.5 ha. Within these areas, and avoid development activities and/or planting any potentially competing trees. Reserve these areas for whitebark pine and/or limber pine replanting and/or recovery work.
    b. Identify any local sites (high or low density stands) with ongoing whitebark pine and/or limber pine research and monitoring plots or deliberate restoration/planting activities are occurring. Within these sites, avoid any activities that are not compatible with restoration/research objectives (communicate with project leader).

Although not captured in the current critical habitat identification, individual trees occurring in low-density stands require protection from harvest and application of appropriate setbacks depending on the nature of the activity, in accordance with applicable laws and prohibitions.

Maintaining a natural mosaic of age classes on the landscape increases resilience to mountain pine beetle attacks, ensures continuous recruitment of cone-bearing trees, and sustains the diverse range of values provided by these species. Where information is available, manage stands within the historic range of natural variability with respect to disturbance regimes, species distribution, and age classes.

References

Environment Canada. 2017. Recovery Strategy for Whitebark Pine (*Pinus albicaulis*) in Canada [Draft]. Species at Risk Act Recovery Strategy Series. Environment and Climate Change Canada, Ottawa. 57 pp.

Alberta Energy Regulator. 2013. Enhanced Approval Process Integrated Standards and Guidelines. Government of Alberta, Edmonton, Alberta. 94 pp. http://aep.alberta.ca/forms-maps-services/enhanced-approval-process/eap-manuals-guides/documents/EAP-IntegratedStandardsGuide-Dec01-2013.pdf

4.3.2 Habitat identification – stand level

Relevant stand level information depends on the project. Variables to collect may include:

- overstory and understory species composition and percent cover – verify if cover percent is proportions or absolute
- substrate type, geological and soil characteristics
- meso or microtopographic features
- rust hosts
- fuel loading
- health status
- size class distribution
- mortality data
- other

4.4 Plus trees

4.4.1 Selecting & documenting plus trees

Plus-tree selection needs to consider the health status of the stand that the tree is selected from. The tree must be in demonstrably better health than the average health status of trees in the stand to demonstrate there is some selection for disease resistance. The more stringent the selection for apparent field resistance, the more likely the tree will have confirmed heritable disease resistance when tested. Testing verifies whether a tree has some type of disease tolerance or resistance, or if it just happened to escape getting infected in the field – or whether field inspection missed some infections, as is likely in taller trees with large crowns.

To date, screening results indicate approximately 20-50% of selections have resistance that is worth retaining (e.g. not in the worst quartile). This means that many more trees must be selected and screened than are retained in a breeding and restoration program. However, even using untested field selections for restoration is assured to increase the proportion of disease resistant or tolerant individuals in a stand compared to no selection.

Examples of selection criteria are in the *Whitebark Pine Cone Collection Manual*, *A Range-wide Restoration Strategy for Whitebark Pine* (Pinus albicaulis), and *Promoting Whitebark Pine Recovery in British Columbia.*

References

Ward K., Shoal R., and Aubry C. 2006. Whitebark pine cone collection manual. Pacific Northwest Region, USDA Forest Service. 12 pp. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5279023.pdf

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Pigott, D., Moody, R., A. Clason. 2016. Promoting whitebark pine recovery in British Columbia. Report to Society for Ecological Restoration BC and BC Ministry of Forests, Lands, and Natural Resource Operations. 110 pp. http://sernbc.ca/pdf/Whitebark_Pine/Promoting%20Whitebark%20Pine%20Recovery%20in%20BC.pdf

4.4.1 Protecting and marking plus trees

Plus-trees are rare, highly valuable and must be protected.

Most importantly is maintaining spatial records of all plus trees. Making their spatial locations known to land managers, wildfire managers, resource planners, industry, and permit reviewers through GIS layers, information sharing, habitat identification, and other means is the first step. The spatial data record needs to identify a species at risk that is a specific individual with high value, or a stand or polygon with numerous plus trees. This enables land managers and project proponents to specifically address these high value trees in wildfire management, land use planning, and project design.

In the field, each plus tree must be clearly and uniquely marked and identified. Tags, flagging, paint, or whatever means is permitted in the area should identify the tree to crews working there – ideally some agency contact information would be available.

Protecting plus trees from mountain pine beetle is essential. Verbenone is a pheremone that is widely available, safe to use as directed, comes in several formulations (powder, pellets, packets, foam), and reduces mortality on whitebark pine trees from beetle attack by around 50%, but not at very high beetle infestation conditions. Installing verbenone in the stand as directed can affect beetle distribution and reduce pressure in a stand near plus trees. Cabaryl and Sevin are also approved for use in some jurisdictions, but have more adverse effects for health and environment. Application annually before beetle emergence (April to June depending on location) is recommended.

4.5 Collecting seeds/seed & cone handling

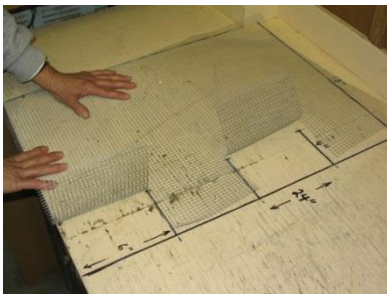
4.5.1 Seed and cone collection

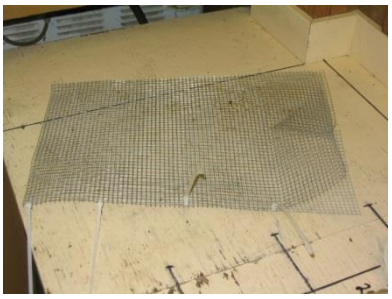
- For limber pine, 1/8” hardware cloth is essential because the cones of limber pine open when mature and release the seeds, which would fall out of the ¼” mesh.

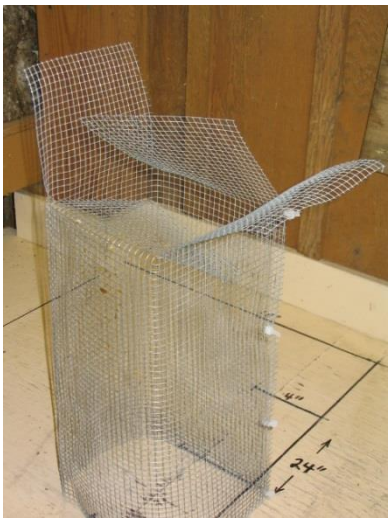
- Avoid collecting from squirrel caches and cones pecked open by birds as these are likely to contain bacteria and fungi that can contaminate the seedlot and impair germination and seed viability.
- Some collectors recommend using a tarp when collecting cones to avoid contact with the ground and reduce potential contamination with common pathogens like *Fusarium* or *Phythophthora*.
- Sterilizing cages between seasons is also considered a good practice.
- Ensure cages are secured well to branches to prevent wildlife from getting in.
- Cage cones as soon as stands are accessible
- Collect cones as late as possible to ensure good seed maturation – try some cut tests to check if most of the embryo cavity is filled, and whether the megagametophyte (the white tissue surrounding the embryo) is solid and white and fills the seed.

The USDA publication *Whitebark Pine Cone Collection Manual* has detailed instructions, as well as guidance on selecting stands and trees to collect from. These cages are flat screen door mesh, crimped manually around branches. There have been some observations that these cages can be pecked and chewed through by determined wildlife, and also that if cages are not made large enough, they can squish the cones and impede their development as they grow inside the cage, making seeds harder to extract and potentially having some impacts on seed viability.

A larger, rectangular more rigid cage design has been successfully used for collecting both whitebark and limber pine cones – a template has been provided by Don Pigott, Yellow Point Propagation (see images below). Cut hardware cloth into 24” x 18” rectangles, then cut 3 evenly spaced 4” deep slits into the 24” side (6” apart). Fold the long side in half and secure the 18” edge with several zip ties to make a flat 18” x 12” rectangle. These easily stack on a pack frame or backpack. When ready to install on a tree, fold into a box, with the open bottom end placed on the branch and the four flaps overlapping the top, secure all four with a single tie. Crimp or zip tie the bottom securely around the branch to prevent wildlife from entering.







Always keen to test new ideas, Don also tested plastic mesh tubing designed for aquaculture in *Plastic Cone Cages - Updated Report* and found that wildlife damaged half the cages when it was not a mast year and all cones were caged, although they were light, cost competitive and easy to work with. (The article also features a great photo of a happy fat squirrel caught red-handed inside a cage.)

Michael Murray also invented the Tree Tong, described in this article *Cone collecting techniques for whitebark pine* that crimps cages over branches – accessibility depends on how long the tongs you construct are.

Seed and seedling availability seems to be always limited. It is recommended that, wherever possible, as many seeds as possible be collected from each tree. Seeds surplus to current and planned needs can be made available through seed banks and seed sales to support restoration projects in the region where there is not enough seed.

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Pigott, D. 2016. Plastic Cone Cages - Updated Report. Nutcracker Notes 30:11. http://whitebarkfound.org/wp-content/uploads/2013/07/NutNotes-Spring-2016-digital.pdf

Murray, M.P. 2007. Cone collecting techniques for whitebark pine. West. J. Appl. For. 22(3):153–155 http://www.fedgycc.org/wp-content/uploads/2015/06/ConeCollectingTechniques_000.pdf

4.5.2 Cone handling

- Always be mindful that seeds contain little living baby trees and they should be treated properly.
- It is paramount when handling cones to make sure they are always well-aerated and cool. Cones should be removed from sacks and spread out thinly in a cool location with good air circulation as soon as possible upon returning to the handling facility.
- Cone sacks should be well vented – NEVER use plastic bags. Burlap sacks, grain bags or even pillow cases will do. **Seeds are alive** and they create a surprising amount of heat as they respire. Fungus and bacteria will grow and damage the seeds.
- **Labelling your cone sacks:** ensure proper labels are both inside and outside the sack to keep track of the cone origin so the right seedlings are planted in the appropriate location. Accidents do happen so if one tag is lost or forgotten, there is a backup.
- **If cones are being collected operationally**, all trees from the stand collection can be combined together.
- **If the seeds are being collected for gene conservation, research, or disease screening**, each tree must be collected in a separate sack. Keeping the correct identity of each tree is absolutely critical. Keep proper records of what was collected, and tag each sack inside and outside.
- Each stem must be considered a separate tree unless it is obvious they are one individual (e.g. a fork above 130 cm). This is because genetic studies show that when nutcrackers plant seeds in clumps, the individuals can germinate and easily graft together because they are usually related. Seeds even in the same cone can have different pollen parents, so they are called “half-sibs” because they share the seed mother tree but may have different pollen father trees, and this also highlights why when trees are tested for disease resistance, there is variation in the seedlings from a single tree.
- **Extracting seeds:** This is generally a manual, labor-intensive process. After cones are well dried, the cone scales break off easily releasing the seeds. Keep the seeds as clean as possible from debris to be able to get accurate counts by weight of your inventory.
- **Storing seeds:** Recent work shows that because of their high fat content, these seeds might not last as long as other species – but there are not a lot of published studies. Many factors affect seed quality and longevity so it also depends on the collection date, seed health, how they were treated

in storage, etc. Seeds should be dried to the water activity level or moisture content specified by the agency that will store your seeds, and accompanied by all relevant documentation.

4.6 Monitoring stands for health & stand dynamics

4.6.1 Transects and monitoring plots

Numerous studies have established different methods to suit particular objectives. Proponents and land managers are **strongly encouraged to adopt the standard methodology of the Whitebark Pine Ecosystem Foundation** as it is readily added to existing data sets to enable regional and cross-jurisdictional comparisons.

If that is not suitable for the stand characteristics or project objectives, consider first assessing the *Interagency Whitebark Pine Monitoring Protocol for the Greater Yellowstone Ecosystem*, then review existing literature for methods that can be adapted or directly used for your project or study and area.

Another resource is the USDA Region 6 publication *Core Data Attributes for Whitebark Pine Surveys* that describes very similar data requirements to the above sources.

References

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4.6.2 100-tree survey

If recent health data is not available from a health transect or other standardized assessment, a 100-tree stand survey is recommended. Data is entered into a standardized worksheet that automatically calculates the percent rust infection, average number of cankers per tree, and percent beetle attack. For electronic copies, contact the Whitebark Pine Ecosystem Foundation (US or Canada), or the USDA Coeur D'Alene Nursery – or generate one using the template below.

USDA Forest Service, Parks Canada (Rocky Mountain National Parks), and Alberta have been successfully using this quick and quantitative assessment that was developed by Mary Frances Mahalovich. Brenda Sheppard and Tracy McKay of Jasper National Park standardized the protocol to ensure the assessment captures representative characteristics of the stand. These directions may not be suitable for all stands (e.g. krummholz or young stands) where surveying 100 representative and well distributed trees may have to suffice.

1. As you hike up into the stand, start the survey when you are in a "representative" area of the whitebark stand – this may be difficult to determine. Some guidelines for a "typical" stand:

   a. Most whitebark pine trees observed have a DBH of 10cm or greater.
   b. Whitebark pine makes up the majority of the stand (i.e. species composition).
   c. Basal area is >2m^2/ha (at least two trees "in", using a prism with a BAF of 2).

   Note: If you are in a stand of low density, or small stand, etc., you may just have to start the survey as soon as you see whitebark. If this is the case, you can always adjust your surveying strategy as you go along.
2. Record the UTMs of the start of the survey. Save current track, clear track log, and start a new track at the beginning of the survey.
3. After classifying the first tree of the survey, pace out 10m north of this tree, and use the prism to estimate whitebark basal area. If the initial basal area is less than 2, plan to classify every tree. If the initial basal area is between 2 and 4, classify every other tree; basal area between 4 and 6, every third tree. You may have to adjust this as you go along.
4. Working with each person approximately 10m apart (i.e. uphill), traverse the slope, classify trees according to live or dead, and number of cankers (class). Call out the canker class to the recorder (who will tally it on the datasheet), or record it in your notebook to be transferred later.
5. Continue classifying (up to 100 trees) until there is a break in the stand, an obvious change in the stand, or a topographical feature that causes a break (e.g. stream, gully, cliff!). At this point, move uphill until the lowest person is 10m higher than where the highest person was in the previous traverse, and continue back across the slope.
6. During the 100 tree survey, use the prism to do a basal area measurement every 25 trees, i.e. after the 25th tree that is classified, and again at 50, 75, and 100. After classifying each of these trees, make sure you pace out 10m north of the tree to do the prism sweep.
7. If the basal area changes significantly, and it is now in a different category (see 3), change the classification strategy, e.g. now do every tree, etc.
8. For each tree that is classified, mark it in the GPS as "WBP" if uninfected, "BR" if infected with rust, or "MPB" if a beetle-kill tree.
9. Any potential "plus trees", or resistant or monitoring trees observed along the way must be carefully checked top to bottom with binoculars before considered. Plus trees must meet the following criteria:
   a. No signs or symptoms of blister rust, OR, old cankers only on a premium tree – see notes in 9 below.
   b. Overall good health – no signs of drought stress, etc.
   c. DBH>10cm (for potential trees; monitoring trees may be smaller).
   d. Climbable (potential for caging), or climbable in the future (monitoring trees)
   e. >100m from the nearest plus tree.
10. In some cases, we find large, "matriarch", generally healthy trees in a stand that show some signs of old infection – old cankers, dead branches, etc. If the tree is in very good health, has a good cone crop, is climbable, etc., and is otherwise optimal, this tree should be carefully checked for any signs of recent infection. If none found, this tree may be selected for caging.
11. If a resistant (plus) tree has been identified:
   a. Tag it! And record tag number.
   b. Name it according to abbreviation of stand, etc.
   c. Record DBH (cm), height, health notes, elevation, climbing notes, etc. according to datasheet.
12. Once 100 trees have been surveyed, record the UTMs of the end of the survey. Continue traversing the stand to search for more resistant trees. Remember to keep marking trees surveyed every 25m or so.
13. Make sure all relevant stand data has been recorded (see datasheet).

Whitebark and Limber Pine Blister Rust & Mountain Pine Beetle Survey Form

Automatic Calculation Sheet - type in the yellow cells only

SPECIES

AREA NAME

STAND NUMBER

BLISTER RUST

CANKERS PER TREE CATEGORY	NUMBER OF LIVE TREES PER CATEGORY	NUMBER OF DEAD TREES PER CATEGORY	TOTAL TREES PER CATEGORY	AVERAGE CANKERS PER TREE FOR CATEGORY	TOTAL TREES x AVG CANKERS
0			0	0	0
TOTAL TREES WITH 0 CANKERS >			0		
1-9			0	5	0
10-20			0	15	0
21-40			0	31	0
41-75			0	58	0
76-150			0	113	0
150+			0	150	0
TOTAL TREES WITH CANKERS >			0		
TOTAL TREES SURVEYED [Trees with 0 Cankers + Trees with Cankers] >			0		0 < SUM OF TOTAL TREES x AVG CANKERS

TOTAL TREES WITH CANKERS / TOTAL TREES SURVEYED x 100 =

Percent of Stand Infected with Blister Rust #DIV/0!

SUM OF TOTAL TREES x AVG CANKERS / TOTAL TREES SURVEYED =

Stand Average Number of Cankers per Tree #DIV/0!

MOUNTAIN PINE BEETLE

NUMBER OF LIVE TREES WITH MPB HITS	NUMBER OF DEAD TREES WITH MPB HITS	TOTAL TREES WITH MPB HITS
		0

TOTAL TREES WITH MPB HITS / TOTAL TREES SURVEYED x 100 =

Percent of Stand Infected with Mountain Pine Beetle #DIV/0!

SURVEYOR DATE

4.7 Clark's nutcracker and other seed predator surveys

There are numerous protocols available depending on what the study objective is: use, habitat suitability, occupancy, home range size, genetic diversity, density, carrying capacity. As Clark's nutcrackers are highly mobile seed predators, surveyors should be familiar with variables which may limit their presence; such as cone maturation or harvest level. A site may have very low nutcracker presence prior to and following cone maturation but have very high visitation when cones are mature.

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4.8 Germinating seeds and growing seedlings

4.8.1 Seed Stratification and Germination

Stratification of whitebark pine seeds is a time consuming but necessary process. Stratification is extremely important – it mimics development in caches overwinter while embryos that are immature when cached can mature in cool moist conditions. Some steps to improve germination, such as seed coat nicking, are suggested by some but there is some debate about the merits of nicking or scarifying the seeds, which can be quite time consuming. Some studies find it is worthwhile, increases emergence rates or consistency, while others find no difference at the end.

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4.8.2 Seedling production

There is up to a 4-year window between collecting seeds and being able to plant a 2-year-old seedling because of the long stratification time, slow growth, and other biological windows. Planning is absolutely essential! There is often more demand than availability of seedlings. Consider growing extra, and establishing a regional "seedling bank" where restoration projects can purchase and use unallocated seedlings for current year projects. Non-profit groups are often looking for current year projects, and the multi-year timelines required to work with these species makes it challenging, so a seedling bank is a good fit.

Studies to date have found that a robust 2+0 plug has better overall survival than a 1-year seedling, and better than planting seeds.

The following nurseries have either experience growing 5 needle pines for restoration for clients, or have the capacity to do so. Check with them first to confirm if they will do the stratification, or if the seeds need to be stratified in advance.

1. Skimikin Nursery Ltd, Tappen BC (highest success, lowest cost growing whitebark)
2. Woodmere Nursery Ltd, Telkwa BC (variable success in whitebark)
3. Landing Nursery Ltd, Vernon BC (good success in whitebark, low volume)
4. Tipi Mountain Native Plants Ltd, Cranbrook BC (have grown whitebark and limber)
5. Splitrock Native Plant Nursery, Lillooet BC (have stratified and grew some whitebark, low success rate)
6. Grumpy's Greenhouses & Landscaping, Beaver Mines, AB (have grown some limber pine, and had blister rust issues as they are in a rust epicentre)
7. Industrial Forestry Service Ltd, Prince George BC (grow custom orders for Parks Canada and others):
8. USDA Coeur D'Alene Forest Nursery, ID (grows high volumes of USDA Forest Service 5NP seedlings). Shipping seedlings to Canada may be an issue because of blister rust - phytosanitary and import permits are needed for both seeds and seedlings.

References

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4.9 Planting seedlings

Planting whitebark pine seedlings is a necessary but laborious process. Access is often difficult and timing windows can be very short. There is a good summary of planting trials discussed in Nutcracker Notes[3]. The most important feature for success is that a sheltered microsite is within 50 cm of the seedling, and the seedling is on the shady side. This reduces insolation and exposure damage, provides shade, prolongs snowmelt and provides up to 3 weeks longer growing season by moderating the microclimate of the seedling.

For planting season, fall or spring are best, depending on snowpack, access, and whether the site is prone to a severe summer drought.

[3] http://whitebarkfound.org/nutcracker-notes/

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4.10 Disease resistance screening

Identifying disease resistant individuals through rust screening programs is widely held as the key to successful whitebark pine recovery. Options available currently are field screening, to plant trees of known origin in a field trial and monitor for infection rates and signs of disease tolerance or resistance; and controlled screening, where seedlings are infected under controlled conditions and monitored for symptoms over a shorter period of time (usually 4 years). These options complement each other because conditions in the field and in a facility may differ, spore loads may differ, spore virulence and environmental factors may differ, and so on – performance in one environment can give a reasonable indicator, but certainly not an exact measure, of performance in another.

For detailed rust methods used, detailed reports are available from USDA Forest Service facilities at Coeur D'Alene Forest Nursery and Dorena Genetic Resource Center, and from Michael Murray or Ward Strong at BC Ministry of Forests, Lands and Natural Resource Operations. In general, the procedures entail growing numerous seedlings from each parent tree to be tested, inoculating them with spores from *Ribes* leaves until they reach a set spore load (usually ~3000 spores/cm is optimal to distinguish resistance mechansisms without overwhelming natural resistance levels)

For limber pine, which has been found to have a single major gene conferring total resistance, rapid screening of seedlings is possible, and studies are underway to identify a genetic screening tool for immediate identification. However, it is not considered a robust restoration strategy to rely on a single gene because the pathogen can evolve much faster than the tree, and a single resistance gene can, and has been, overcome by pathogenic evolution. Combining multiple resistance mechanisms is optimal for the most durable long term resistance program.

Having consistent expert assessments of blister rust symptoms is critical. There are many types of resistance mechanisms, and the signs can be subtle. A trained and patient expert examining each seedling thoroughly provides the most consistent and reliable data. Given the cost and time of screening it is definitely worth it to contract this activity out to professionals who are experts on the subject.

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4.11 Scion, pollen, and aeciospore collection

4.11.1 Scion collection

Scion material is often collected from plus trees for grafting to rootstock to produce seed orchards to produce rust resistant stock. When collecting scion for grafting, it is most important when collecting scions to make sure rootstock is available. Match the scion diameter with the rootstock diameter. Scion can be stored for months dormant, moist, at 1-4°C. The best results are from scion collected when fully dormant, but good success has been reported from early dormant cuttings (collected October to December), and moderate success has been reported from non-dormant cuttings (collected during the growing season). Nutcracker Notes has some articles on hot grafting. When collecting scion material, it is best to contact the grafting nursery for protocols; however some general guidelines are provided here:

- Collect at least 4 to 9 cm of current year growth, plus several cm of the previous year's growth so grafters can cut to suitable length and diameter.
- Match diameter to that of the rootstock.
- At least one full, intact bud from a vigorous branch should be collected – upper branches are preferred for growth form reasons.
- Scion should be free from insect and disease damage and have a full set of healthy needles.
- For transport of scion material, wrap cut ends with moist paper towels but no free water, in ziplock bags at 1-2°C.

4.11.2 Pollen collection

In some instances, seed orchards may require pollen collections for breeding purposes. It is probable that orchards will provide guidelines for collection; however, some protocols from the USDA Forest Service Nursery in Coeur D'Alene are provided here:

1. Locate trees and assess for pollen development. Flag elite trees ahead of time to facilitate relocation before actual pollen collections take place. Record as much pollen identification information on the outside of the bags ahead of time, to speed up actual field collections.
2. If you are collecting pollen from the same trees or same locations in different years, when to monitor for ripeness can be based on past experience with adjustments made for that year's climate. An "indicator" tree close to your office can also be used, based on experience with that tree's ripeness relative to target trees in the field. It is always better to be a little early and make a second visit than too late and have to wait until next year.
3. Hopkin's Bioclimatic Law can be used to estimate pollen ripeness dates for trees in new locations relative to locations where ripeness dates are known. In general for the Northern (US) Rockies, pollen ripens:
   - 4 days later for each 1° latitude northward and 4 days earlier for each 1° latitude southward
   - 4 days later for each 5° longitude eastward and 4 days earlier for each 5° longitude westward
   - 4 days later (earlier) for each 400 ft/122 m increase (decrease) in elevation

   This should be used as a general guideline only because of microsite differences such as aspect, cold air drainage, and the genetics of the tree (early ripeners vs. late ripeners).

4. Monitor catkins for signs of ripening; be aware that you have ~ 24-36 hours to collect mature pollen before pollen flight. Things to keep in mind:
   - Trees ripen from the bottom up, unless there are cold air drainage issues
   - Perform the squeeze test (squeeze a catkin between thumb and finger, if liquid is yellow and/or cloudy, the pollen is not ripe. If the liquid is clear, pick the catkins).
   - If near neighbors are shedding pollen, and there is a risk of pollen contamination at the target elite tree due to air movement, do not collect pollen.
5. Place catkins in paper lunch bags or pollen bags. Seal seams with tape to avoid contamination with other pollen collections. Collect 2 to 3 bags of catkins per tree and do the following;
   -Fill bags 1/3 to 1/2 full with catkins only--NO NEEDLES
   - Double fold the top of the bag shut and staple closed. Do not fold bags so far down that the catkins are packed together with no "breathing room." Seal the stapled fold with tape.
6. To avoid pollen contamination when moving from one elite tree to the next, sterilize all collection tools (snippers) and hands with rubbing alcohol and allow sufficient drying time before proceeding with the next collection. A new pair of disposable Surgical gloves are recommended for hands in lieu of repeated skin contact with alcohol.
7. Do not collect catkins in the rain or in wet, extremely humid conditions. This greatly increases the chances of mold growing on the catkins before the pollen can be processed at the Nursery. Mold decreases pollen yield and viability.
8. Use red tape or staple red flagging to the top of the bag to indicate “red tag” pollen lots that need to be processed for use that same field season. Also, write “red tag” on the bag.
9. Record collection and identification information with a waterproof marker.
   a. Plantation Collections (PP) record the following information on the bag:
      - Indicate if this is a “red tag” lot.
      - Collection Date _____/_____/_____
      - Species Code _____ (2 alpha, PP)
      - Plantation Code_____ (4 alpha, e.g., LONE, COND, LUBR)
      - Breeding Zone_____
      - Family Number_____
      - Pedigree Number_____
      - Elite Tree Rep_____Row_____Col_____
      - Collected by_____
   b. Single-tree collections in stands (WP) record the following information on the bag:
      - Indicate if this is a “red tag” lot.
      - Collection Date _____/_____/_____
      - Species Code _____ (2 alpha, WP)
      - TWN_____ RNG_____ SEC_____ ELEV_____
      - Cycle Number_____
      - Family Number_____
      - Collected by_____
10. Temporary storage. Keep bags cool and dry, out of direct sunlight while in the field. If unable to ship pollen within 24 hours, hang bags on a clothes line in a garage or warehouse, with clothes pins, and be sure to shake the bags twice a day to ensure air circulation and minimize mold formation. Ship bags within 48 hours of collection.
11. Transport pollen collections in a cardboard box that is loosely packed with crumpled newspaper. Cut 2" diameter holes around the sides of the box for aeration. Tomato or apple boxes work well.

12. Ship pollen to the Nursery. Notify staff prior to shipment. Ship to arrive during posted business hours

4.11.3 Aeciospore collection

Aeciospore collections may be required to infect Ribes beds with white pine blister rust to support rust screening activities. The following protocol is from the USDA Forest Service Coeur D'Alene Forest Nursery.

There are several ways to collect spores. The cyclone spore collector, scrape and filter, and prune and tap methods each have advantages and disadvantages. The cyclone collector can be obtained by contacting David Foushee at dfoushee@fs.fed.us or phone (208) 765-7394. When using this method, care must be taken to avoid sucking up trash which plugs the needle-like nozzle. A fine wire must be used periodically to push trash out of the nozzle. This method produces the cleanest collection of spores but the least volume per unit of field time. If windy conditions are unavoidable, the least amount of spores is lost in the wind with this closed system. The tapping of pruned branches or excised cankers to release spores over a piece of paper or the scraping of cankers over a container are preferred by some field units. These methods produce a larger volume of spores but require an extra step of filtering to remove trash. Care must also be taken to shield against the wind when using these tap or scrape methods.

The goal of each method is to collect 10-20 cc's of clean, dry spores with a minimum of 5 cc's.

Cyclone Spore Collector

1. The bulb on the cyclone spore collector (below) discharges air out of the one-way valve at the rear, when it is compressed.
2. Air is drawn in through the spore collector when the bulb is released and expands.
3. A small amount of air may be released through the spore collector itself when the bulb is compressed. Since spores can be dislodged by even the slightest air movement, it is best to point the nozzle of the spore collector slightly away from the canker when compressing the bulb.
4. Before releasing the bulb, re-aim the nozzle of the cyclone spore collector at one of the aeciosacs on the canker. Hold the nozzle within 1/8th of an inch of the aeciosac.
5. Release the bulb in one quick movement and aeciospores will be drawn out of the aeciosac, through the cyclone spore collector and into the glass vial.
6. Use the end of the spore collector nozzle to open the aeciosac if not already ruptured.
7. Work from the top of the canker to the bottom, systematically collecting spores from the aeciosacs as you go.
8. More than one press and release cycle may be required to collect all of the spores from large aeciosacs.
9. Remove stopper and replace the glass vial when it becomes half-full of spores.
10. Partially screw the black lid on the glass vial, just long enough to take the sample out of the field and get it back to the office without spilling the contents.

Other collection Methods

- Cutting a limb or excising bole cankers from smaller trees with a pair of pruners and simply tapping over a piece of paper to release spores.
- Scraping off spores with a pocket knife into a soil canister or glassware with a lid (see note on moisture below). This method results in dirt, bark, etc. getting mixed with the spores. A fine mesh chiffon fabric can be used to filter out debris to get a clean, pure spore sample.

Spore handling and processing

Spores that are shedding naturally still have far too much moisture to be transported in a "sealed" container for longer than about an hour. As a safeguard to prevent the growth of mold, field collections should be dried further in a suitable indoor location prior to shipment to the Nursery. Carefully pour the contents of the glass vial or other container onto a sheet of wax paper or other slick surfaced paper and spread the spores out in a thin layer. Protect the spores from air movement and allow them to dry in a low humidity room at 68-72°F/20-21°C as needed. When dry, pour the contents into a paper envelope. The envelope should be labeled with enough information for cross referencing with the aeciospore collection form which is included with the shipment. To prevent leakage, it is mandatory that all seams be sealed with scotch tape prior to filling the envelope with spores. The sealed envelope must be kept relatively cool and out of direct sunlight.

As soon as possible after adequate drying, spore collections should be either hand delivered or shipped priority overnight to the following address: Deliveries must arrive during business hours. An aeciospore collection form with the collection information (see section above for pollen) must accompany the collection.

4.12 Silviculture: thinning, pruning, planting. etc.

There have been numerous studies on thinning and several on pruning, but most have not yet reported results because of the slow growth and long succession times for whitebark and limber pines. Some studies lack data on pre-treatment densities and composition, some (generally operational trials) have no replication, and others lack untreated controls.

When planning silvicultural treatments, including measurements and reporting of control and pre-treatment conditions is advised to accurately quantify treatment results, and consider including some replicated plots.

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4.12.1 Pruning and excising cankers

While highly effective for western white pine to mitigate blister rust, there is not yet clear data to assess the effectiveness of pruning for whitebark or limber pine but a few trials have been initiated. In western white pine, removing lower branches which are the primary source of infection from spores in the understory does improve rust levels in individual trees and stands. This treatment is extremely expensive and restricted to high value stands. For whitebark and limber pine, the high frequency of upper crown infections due to wind eddies in mountainous habitats casts some uncertainty on how effective this might be, but study results are anticipated within several years.

Excising cankers similarly has been done in western white pine, but not in whitebark or limber pine so there is no data. Generally, cankers that are close to or reach the bole are considered terminal in susceptible trees.

4.12.2 Planting

Virtually every reported study and management guideline recommends planting resistant seedlings – either from tested trees or selected plus trees. This is sound advice, backed up by extensive modelling and field data that reflects how increasing the proportion of disease resistant trees in a stand, and across the landscape, will lead to positive outcomes for recovery where stands can ultimately sustain themselves.

Scott et al. (2011) identified nine guidelines for planting whitebark pine seedlings:

1. Plant large hardy seedlings;
2. Reduce overstory competition to increase growing season length;
3. Encourage planting in areas where whitebark pine is known to grow or has grown in the past, and avoid mixed species planting as whitebark pine tends to be readily outcompeted;
4. Reduce understory competition, especially grasses and sedges, to reduce moisture competition;
5. Consider ridge tops or exposed slopes for most planting and avoid frost pockets and areas with pocket gophers;

6. Plant in suitable microsites to improve water utilization, reduce heat stress, and protect the seedling from trampling.
7. Avoid planting next to tall snags which may fall over and uproot the seedling;
8. Plant appropriate densities to account for anticipated mortality and support large crown formation in mature trees; and
9. Plant when there is adequate soil moisture and avoid planting during drought periods.

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4.12.3 Thinning

Nutcracker Notes has numerous project examples, but as noted, results are expected to take years to be able to assess treatment effectiveness due to slow growth, as well as sample size limitations in some studies or projects. A good compendium is found in *A Range-wide Restoration Strategy for Whitebark Pine (*Pinus albicaulis*)*.

Thinning to remove competition is one of the most common silvicultural treatments besides planting seedlings. To balance treatments cost and be able to treat the largest area, different thinning approaches have been tried: thinning only shade-tolerant competitors, thinning a certain radius around whitebark pine, or thinning all competition.

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4.12.4 Burning

Burning has produced mixed results. Studies often suggest that recovery times to gauge success need one or more decades. Fire severity is a very important factor to consider as damaging cone bearing mature trees and plus trees is an unwanted side effect. Numerous studies reported no regeneration in the first five to ten years post-fire (both for wildfire and prescribed fire), while other studies have found extremely variable regeneration densities. There seems to be little consistency in results, but in general most studies do find increased regeneration in burnt areas compared to unburnt, with frequent observations of nutcrackers caching.

Use of prescribed fire and wildfire in whitebark and limber pine habitats in the Crown of the Continent will be addressed in more detail by that working group.

4.13 Management planning

4.13.1 Prioritizing areas for management

Consult with regional planners to determine if there is a restoration or management plan for your area that identifies priority landscapes for whitebark and limber pine work. If not, priorities can be set based on the principles in *A range-wide restoration strategy for whitebark pine* (Pinus albicaulis). Obviously having a reasonable inventory of where stands are, and what condition they are in is a prerequisite for effective planning and prioritization. If available, use a spatial inventory of habitat suitability and capability, combined with locations of plus trees and other attributes of interest. Once this is determined, then priority and ancillary activities, with quantifiable targets, should be allocated to each area.

Depending on the management objective, quantitative thresholds have been published for various stand attributes. For instance, Barringer et al. 2012 identified a threshold of 1000 cones/ha, equivalent to approximately 2 m^2/ha of whitebark pine basal area to sustain nutcracker visitation rates, while earlier studies indicated at least 5 m^2/ha was recommended for a healthy functioning stand. Keane et al. (in prep) recommended 25 mature whitebark pine trees per hectare as a benchmark for a marginally viable stand, while under 10 trees was found in some studies to be too sparse to attract nutcrackers for recruitment. Schaming (2016) found that Douglas-fir stands adjacent to whitebark pine, or within foraging distance, were essential habitat attributes to sustain nutcracker site fidelity near whitebark pine stands.

Published reports show incredible variability in densities of seedlings, saplings, and mature trees with little consistency because of this broad range and highly variable distribution. Stand health, time since disturbance, disturbance severity, stand composition, and other factors all have significant influences on five-needle pine abundance. Collecting local and regional stand data is still important to capture the range of variablity for a given project area. Unfortunately, in many areas, especially within the Crown of the Continent, stand health has been impacted so severely that a healthy reference baseline is difficult to establish.

Where appropriate, ensure that reforestation and reclamation plans include whitebark and limber pine as preferred or suitable species.

Establishing a centralized database for tracking of reclamation and reforestation projects with whitebark and limber pine is required, as metrics may differ from standardized reforestation tracking systems. Compiling all available data will provide a more effective assessment of what works well, and what approaches should be changed or scrapped.

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4.13.2 Breeding and seed production for disease resistance

The USDA Forest Service Northern, Rocky Mountain, Southwestern, and Intermountain Regions have successfully established four seed orchards of grafted, screened rust resistant selections adapted to local seed zones. The Regional Geneticist has spearheaded an integrated program for many years where land managers have supported selections, cone, scion and spore collections, and are strong proponents of restoration.

Grafted orchards can, with proper nursery culture, produce pollen and cones several decades earlier than having to wait 50 years for a seedling to mature. Controlled crossing of these selected trees ensures a supply of well-adapted seedlings that are not contaminated with pollen from susceptible trees in a wild stand. Over the long term, seed orchards are an important tool for recovery.

Others have been working to establish seed production areas, which are natural stands that are cultured to maximize cone production. These stands are managed to remove unhealthy individuals and are far less expensive to establish and maintain, but may be subject to pollen contamination from surrounding trees, and only contain the genetic diversity from the existing single stand, unless supplemented with planted trees from other stands that may enhance the diversity of resistance mechanisms.

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4.13.3 Seed zones

A seed zone is an area within which a population of trees is optimally adapted. Seed zones are delineated based on provenance tests, where seeds originating from different areas, climates, and habitats are grown together in different locations and measured over time to determine their performance. Provenance trial results determine how far seeds can be moved from their origin before showing signs of maladaptation and those areas, or climatic conditions, are established as seed zones. Some jurisdictions establish seed transfer as legal requirements, and others as guidelines. Land managers should be familiar with the rules that apply to their area.

Because of their known broad and repeated dispersal and mixing, and their adaptation to harsh habitats, five needle pines and particularly whitebark pine and limber pine have fairly broad seed zones with respect to latitude, longitude, and elevation. Genetic studies of both DNA and other genotypic

evidence, as well as adaptive studies, show that they have historically been transferred by birds long distances, and seed sources have mixed extensively. There are genetic diversity "hotspots" reflected in what were genetic refugia during the last ice age, in several locations in the US cordillera, and each zone reflects adaptations to broad regional climatic and environmental conditions.

Seed zones applicable to whitebark pine have been developed for the Pacific Northwest Region, the Intermountain region, British Columbia and Alberta (these latter two currently use generic seed zones for conifers). Seed zones applicable to limber pine have been developed for its US range and in Canada generic seed zones apply for Alberta and British Columbia.

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