# Alberta Whitebark Pine and Limber Pine Recovery Plan

Alberta Species at Risk Recovery Plan No. 44

Alberta Whitebark Pine and Limber Pine Recovery Plan
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# Table of Contents

# List of Figures

# List of Tables

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# Recovery Planning in Alberta

Albertans are fortunate to share their province with an impressive diversity of wild species. Populations of most species of plants and animals are healthy and secure. However, a small number of species are either naturally rare or are now imperiled because of human activities or natural processes. Alberta Species at Risk recovery plans establish a basis for cooperation among government, industry, conservation groups, landowners, Indigenous communities and other stakeholders to ensure these species and populations are restored or maintained for future generations of Albertans.

Alberta has a robust provincial recovery program to support its commitment to the federal/ provincial *Accord for the Protection of Species at Risk* and the *National Framework for the Conservation of Species at Risk*, and its requirements established under Alberta's *Wildlife Act* and the federal *Species at Risk Act*. An overall goal of the program is to restore species identified as *Threatened* or *Endangered* to viable, naturally self-sustaining populations within Alberta.

Alberta Environment and Parks is committed to providing opportunities for Indigenous communities, stakeholders, and the Alberta public to provide their perspectives and influence plan content during the recovery planning process. The process for how Albertans are engaged can vary based on the socio-economic and conservation issues and the level of interest expressed. Draft recovery plans undergo a review by the Fish and Wildlife Stewardship Branch and are then posted online for public comment for at least 30 days. Following public review, Alberta's Endangered Species Conservation Committee reviews draft plans and provides recommendations on their acceptability to the Minister of Environment and Parks. Plans accepted and approved for implementation by the Minister are published as a provincial government recovery plan. Approved plans are a summary of the Ministry of Environment and Park's commitment to work with involved stakeholders to coordinate and implement conservation actions necessary to restore or maintain vulnerable species.

Recovery plans include two main sections: (1) a situational analysis that highlights the species' distribution and population trends, threats, and conservation actions to date; and (2) a recovery section that outlines goals, objectives, associated broader strategies, and specific priority actions required to maintain or recover *Threatened* or *Endangered* species. Each approved recovery plan undergoes regular review and at that time progress on implementation is evaluated. Implementation of each plan is subject to internal and external resource availability.

Recovery plans will be systematically reviewed every five years. Where there are large changes in the goals, objectives, or strategy sections due to a new understanding or circumstance, a plan may need to be redrafted, consulted on, reviewed by the Endangered Species Conservation Committee, and the changes approved by the Minister.

# Executive Summary

In 2008, whitebark pine and limber pine (“five-needle pines”) were listed as *Endangered* under Alberta’s *Wildlife Act.* This status was due to an observed and projected population decline across the provincial range, caused by white pine blister rust and mountain pine beetle. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed whitebark pine (2010) and limber pine (2014) and recommended an *Endangered* status for both species. Whitebark pine was listed under Schedule 1 of the *Species at Risk Act* in 2012, and a decision on limber pine is pending.

Agencies have changed over time, but are mentioned here as they were at the time. In 2009, the Alberta Whitebark and Limber Pine Recovery Team was established to support recovery planning and work for endangered pines. The recovery team included representatives from Alberta Environment and Sustainable Resource Development, Alberta Tourism, Parks and Recreation, Canadian Forest Service, Parks Canada Agency, and the Alberta Native Plant Council. The Alberta Forest Products Association reviewed the draft plans. Recovery teams for both species have been reconvened as a provincial recovery implementation team to implement and track recovery progress. Members are from Alberta Environment and Parks and Alberta Agriculture and Forestry, with a core membership team and a group of supporting diverse subject matter experts.

Whitebark pine grows in the high mountain forests of western Alberta at treeline and in upper subalpine forests. Its range in Alberta spans from the US border to the northernmost extent of the Alberta Rocky Mountains. Whitebark pine is a slow-growing, long-lived species that may reach 500 years in age, and occasionally exceeds 1000. Limber pine grows from the upper treeline to the montane lower treeline in the foothills and Rocky Mountains. In Alberta it extends from the David Thompson corridor to the US border. Limber pine is also a slow-growing, long-lived species, often reaching 400 years and occasionally exceeding 1000. Whitebark pine and limber pine provide several unique important ecological functions and are considered both keystone and foundation species. Whitebark pine has an obligate relationship with Clark’s nutcracker, the primary seed disperser for both species, and limber pine has a very strong reliance on Clark’s nutcracker for dispersal and regeneration.

The recovery plan will guide the management of these endangered species over the next ten years and beyond, as it will take up to a century to fully gauge the effectiveness of recovery actions because of the species’ very slow growth and reproduction. A seed collected now and planted as a seedling will produce its own seed crop in five to eight decades. The long-term goal of this plan is:

> “to have at least one self-sustaining metapopulation per species and per management unit, of sufficient size, composition, and distribution to sustain Clark’s nutcracker populations within their historical range and support adaptation in their projected future range.”

To achieve this goal, two sequential objectives are identified:

1. By 2100, the rate of increase in the metapopulation of five-needle pine trees with elevated disease tolerance or resistance in each management unit is greater than the rate of decline caused by blister rust.
2. By 2120, at least one self-sustaining metapopulation of each five-needle pine species is established north and south of Highway 1.

Strategies are designed to support these objectives:

Strategy 1: Maximize the frequency of disease-resistant trees in five-needle pine habitat in order to reverse the decline caused by white pine blister rust, supported by:

> Strategy 1.1: Identify, protect and test plus trees (i.e., trees selected in the field for disease resistance).
>
> Strategy 1.2: Develop at least one seed orchard for each species sufficient to supply seed with increased disease resistance to meet restoration needs.
>
> Strategy 1.3: Restore populations in suitable habitat to sustain ecological function.

Strategy 2: Restore fire regime in five-needle pine habitat within the historical range of variability.

Strategy 3: Address priority knowledge gaps.

The necessary actions to implement each strategy are described in this report, with associated progress measures. This recovery plan will undergo periodic review and will be updated as needed.

# 1.0 Introduction

Whitebark pine and limber pine are five-needle pines whose ranges include the montane region of western Alberta. Both species have fascicles (needle clusters) containing five needles, with wingless seeds dispersed primarily by Clark's nutcrackers. These trees are considered "keystone species" because of the importance of their highly nutritious seed for approximately 100 wildlife species, as well as their roles in stabilizing soils, moderating hydrology of headwater streams, and modifying harsh environments where they occur (Tomback *et al.* 2001).

There is an extensive body of literature documenting the taxonomy, ecology, life history, status, threats, and steps to recovery for whitebark pine, and a growing number of studies on limber pine. In the interest of keeping this plan succinct, readers are directed to the wealth of information on these species on the website of the Whitebark Pine Ecosystem Foundation, and to the many other articles and proceedings available, particularly through the United States Department of Agriculture, Forest Service website.

Recovery actions for both species are essentially the same, and the first recovery plans developed for the two species were nearly identical because of their ecological and biological similarities, and similar threats in Alberta and Canada. Recovery strategies and actions for both species are thus combined in this document.

# 2.0 Process for Plan Development

Whitebark and limber pine were assessed as *Endangered* under Alberta's *Wildlife Act* in 2008, a status which has been maintained up to the most recent status assessment (Alberta Environment and Parks 2017). Following the initial assessment, a recovery team was formed in September 2009:

- Erica Samis (2009–2011)/Brad Jones (2011–2014), Alberta Environment and Sustainable Resource Development (co-chair)
- Robin Gutsell, Alberta Environment and Sustainable Resource Development (co-chair)
- Leonard Barnhardt, Alberta Environment and Sustainable Resource Development
- Joyce Gould, Alberta Tourism, Parks and Recreation
- Cyndi Smith, Parks Canada Agency
- David Langor, Canadian Forest Service
- Kelly Ostermann, Alberta Native Plant Council

Meetings were held periodically for several years, including consultation with the Alberta Forest Products Association, until the recovery plans for whitebark pine and limber pine were approved by the Minister of Alberta Environment and Sustainable Resource Development in 2013 and 2014, respectively.

The recovery team was reconfigured as a recovery implementation team, with meetings once or twice yearly to review updates and progress, supplemented by periodic communications. The team currently has the following members:

<u>Core team:</u>

- Robin Gutsell, Alberta Environment and Parks, policy (co-chair)
- Jodie Krakowski, Alberta Agriculture and Forestry, genetics (co-chair)
- Brad Jones, Alberta Environment and Parks, management
- Dale Thomas, Alberta Agriculture and Forestry, wildfire
- Erin Fraser, Alberta Agriculture and Forestry, restoration
- Joyce Gould, Alberta Environment and Parks, science

- Lindsay Robb, Alberta Agriculture and Forestry, seeds
- Margriet Berkhout, Alberta Agriculture and Forestry, wildfire
- Megan Evans, Alberta Environment and Parks, ecology
- Pam Melnick, Alberta Agriculture and Forestry, forest health and adaptation

Supporting members:

- Heidi Eijgel, Alberta Environment and Parks, communications
- Lee Charleson, Alberta Agriculture and Forestry, forest health and adaptation
- Ryan Good, Alberta Agriculture and Forestry, wildfire

Development and implementation of the plan have benefitted tremendously from formal and informal collaboration and support of many agencies. Maintaining and strengthening these relationships is fundamental to success, as each agency contributes unique strengths, such as land base administration, knowledge transfer, and supporting actions.

Collaborating agencies:

- BC: Ministry of Forests, Lands and Natural Resource Operations, BC Parks
- Canada: Parks Canada Agency, Natural Resources Canada — Canadian Forest Service Pacific, Laurentian, and Atlantic Forestry Centres
- US: US Department of Agriculture, Forest Service: Dorena Genetic Resource Center, Coeur D'Alene Forest Nursery, Rocky Mountain Research Station, Intermountain Research Station
- Academia: The King’s University (Edmonton), Montana State University, University of Alberta, University of British Columbia, University of Calgary, University of Northern British Columbia, University of Victoria
- Non-governmental organizations: Whitebark Pine Ecosystem Foundation, Crown Managers Partnership High Five Working Group, Nature Conservancy of Canada

From January 29 to February 2, 2018, and from April 2 to 4, 2019, facilitated workshops were held in Banff to support Canadian recovery planning for limber and whitebark pine. The widely used Open Standards conservation planning methodology was followed, supported by Miradi software designed to assess recovery targets, define scope, condition, prioritize direct and indirect threats, and develop action plans to mitigate the threats in order to achieve quantifiable recovery targets, and track progress. Participants included representatives from all mountain national parks and from Parks Canada’s national office, the Whitebark Pine Ecosystem Foundation, and various departments of the Alberta and BC provincial governments. Attendees included technical specialists and communications and management staff. Workshop outcomes guided elements of this plan.

The Stewardship and Policy Integration Branch of Alberta Indigenous Relations provided guidance on the appropriate levels of First Nations engagement on the plan. During January 2020, 15 Indigenous and Metis bands and organizations were offered an opportunity to comment on the proposed recovery strategies and actions. No comments were received.

Parallel recovery plans for these species are being developed encompassing the US portion of the range and the Crown of the Continent region. These plans include priority gaps identified by the Crown Managers Partnership High Five Working Group, which is a cross-jurisdictional collaboration across the Crown of the Continent region. The working group is tasked with addressing key gaps and drivers for conservation and restoration of high-elevation five-needle pines in the region, which can then be applied across the species’ ranges.

# 3.0 Implementation Progress Review

### *Improving species inventory*

Regression-based modelling of whitebark pine habitat in Waterton Lakes National Park (McDermid and Smith 2008) spurred further projects using remote sensing, topographic modelling and satellite imagery. Habitat suitability models (presence/absence) for both whitebark and limber pine are now available on the provincial Open Data website to guide restoration and management work (Krakowski *et al.* 2017). A comprehensive set of empirical observations is publicly available online via the Alberta Conservation Information Management System (ACIMS). Alberta has compiled detailed records of plus trees (trees selected for disease tolerance or resistance in the field but not yet tested), incidental observations, transect monitoring data and health data in spatial formats. Many of these data, particularly for monitoring transects and data within national parks, are also held by Parks Canada where the work is done collaboratively. Modelling to estimate stem density for Alberta did not meet required accuracy specifications but may be improved in future years as more field data are amassed.

### *Monitoring transects*

A network of ~250 long-term monitoring transects have been established following peer-reviewed protocols (Tomback *et al.* 2005) and are assessed approximately every five years by trained staff and contractors. The data are essential for determining status and trends, and for prioritization of recovery actions. Data provide information on stand and tree health, cone production, stand dynamics, and regeneration (Smith *et al.* 2008, 2011, 2012, 2013; Shepherd *et al.* 2018). Transect locations are in the provincial spatial data warehouse and the Alberta Conservation Information Management System, ACIMS.

### *Other research plots*

From time to time, project-specific plots are established and assessed to provide more information on processes, and data to address specific research questions (e.g., Ernst 2006; McTaggart 2007; Wong and Daniels 2017). The same sites are occasionally used for multiple studies.

### *Fire effects*

Severe wildfires have sometimes killed extensive stands of mature cone-bearing trees and regeneration. No significant differences in natural regeneration were evident between burnt and unburnt whitebark pine sites, which is due at least in part to large variation in fire severity and extent (Moody 2006; Drummond 2018). Dawe (2019) found significantly more limber pine regeneration in unburnt sites and nearly none in burnt sites. Parks Canada has conducted prescribed fires for whitebark and/or limber pine habitat enhancement and creation and is continuing to monitor these areas for recruitment and planting success. Alberta conducted a prescribed burn north of Saskatchewan Crossing in 2009 that affected both whitebark and limber pine habitat. Some high value rust resistant trees (“plus trees”) have been killed by fire. Regeneration takes many years to establish without supplemental planting, but nutcrackers have been observed caching in burnt areas. Suitable planting and germination microsites are abundant, and competition and rust host species are reduced. A fuels project was completed in 2020 to address the relationships between fire and regeneration of five-needle pines and develop best practices.

### *Regeneration*

Studies on characteristics of regeneration improve outcomes of planting prescriptions and promote natural regeneration (Coop and Schoettle 2009; Gelderman *et al.* 2016; Cripps *et al.* 2018). On-the-ground restoration is just beginning in Alberta. Before 2018, Parks Canada planted 1000–5000 seedlings per year in Alberta from whitebark pine plus trees (Smith *et al.* 2011). Monitoring revealed seven–year survival of approximately 50%, with no detectable effects of mycorrhizal inoculation after several field seasons (Cripps *et al.* 2018), despite studies showing potential for mycorrhizal effects to improve seedling vigour (Lonergan *et al.* 2014). In 2018, 1050 resistant, tested limber pine seedlings were planted in a paired long-term monitoring restoration project in Castle Wildland Provincial Park and the 2017 area burned by the Kenow wildfire in Waterton Lakes National Park. Planting and monitoring are planned in each following year to greatly expand the restoration footprint.

### *Gene conservation*

Seed is archived for long-term conservation, sent for resistance testing, used for research projects, and used to produce seedlings for restoration. Projects to optimize seed collection, storage and germination have led to improved methodology (Bower and Aitken 2006; Leslie and Wilson 2011; Robb 2014a,b,c; Riley *et al.* 2016). Parks Canada has been collecting seed from plus trees selected in the field for putative disease resistance for many years (Smith 2009). Ex situ provincial gene conservation activities shifted in 2015 from range-wide seed collections to collecting exclusively from plus trees.

In situ gene conservation for these species consists of assessing the status and gaps of populations in their native habitat, and documenting and protecting high-value trees. Both species are well represented in Alberta’s protected areas. Limber pine has sizeable populations on private lands in southern Alberta, which provides a valuable outreach opportunity. Plus trees are selected from stands with high levels of blister rust, following Mahalovich (2015). Field-tagged plus tree data and records are stored in the provincial spatial data warehouse for use in planning and management. Forest health data are assessed annually and shared among agency partners to aid in research and restoration projects, and protection of populations and plus trees.

### *Seed zones*

Species-specific seed zones and seed transfer provisions in Alberta have been approved for both species, reflecting their unique biology and adaptive patterns (Krakowski 2018). To date, one provenance trial each of limber pine and whitebark pine have been established in Alberta (see Alberta Forest Genetic Resources Council 2017) to assess adaptive population differentiation in order to refine seed zones. The limber pine project has a sister site in Colorado that is testing sources along the Rocky Mountains (Schoettle 2016); the whitebark pine project has a series of larger and smaller sites around BC that are testing range-wide sources.

### *Disease resistance*

Provincial and federal recovery efforts are strongly directed towards identifying and documenting and protecting plus trees, testing them for heritable resistance, and planting their seedlings. Currently whitebark pine plus trees are tested in B.C. at the Kalamalka Forestry Centre and at the United States Department of Agriculture, Forest Service Coeur D'Alene Forest Nursery; limber pine plus trees are tested at the United States Department of Agriculture, Forest Service Dorena Genetic Resource Center (Sniezko *et al.* 2011). Cloning disease-resistant trees through grafting enables genetic duplicates to be preserved in case of a disaster, and maximizes the seed production of each parent tree in a future seed orchard and/or clone bank. Grafting of plus trees has begun for both whitebark and limber pine.

### *Wildlife value*

Studies have supported integrating planning for whitebark and limber pine with planning for wildlife habitat, and habitat suitability rating. Several projects have confirmed opportunistic grizzly bear use of whitebark pine seed in Alberta, primarily in parks (McKay and Graham 2009a,b; Forshner *et al.* 2012; Hamer and Pengelley 2015). Squirrel middens were the primary source of seeds for the bears, although foraging from trees also occurred. Squirrel predation of limber pine has also been studied (Peters and Vandervalk 2009; Peters 2011; Peters and Gelderman 2011), as well as bear use of those middens in Banff National Park (Hamer 2016).

### *System interactions: climate change, health, range limits*

Recent research has illuminated the directionality, nature and tipping points among multiple interacting threats affecting whitebark pine (Six and Adams 2007; Barringer *et al.* 2012; Tomback *et al.* 2016; Wong and Daniels 2017). Factors affecting resilience of whitebark pine ecosystems are particularly key to successful recovery, given the species' dependence on bird-mediated dispersal and regeneration. The northern limit of whitebark pine is likely limited by this system

(Clason 2017), where assisted migration, often proposed as a conservation tool (McLane and Aitken 2012), is unlikely to succeed without sizeable, locally stable populations of the obligate disperser and its main alternate food source (i.e., Clark's nutcracker and Douglas fir) in the new location.

When multiple threats affect the same stand at the same time it can significantly exacerbate decline. Individuals can be susceptible to more than one threat, threats affect age cohorts of trees differently, and trees that survive one threat may succumb to another. For example, a 2014-2018 mountain pine beetle outbreak in Jasper National Park affected almost 50% of the forested area of the Park. Limber pine and whitebark pine stressed by rust infection appear to be more susceptible to attack by mountain pine beetle (Arno 1986; Six and Adams 2007; Bockino and Tinker 2012). Remaining mature whitebark pine under stress from shade-tolerant competitors have a higher probability of rust infection and beetle attack (Kendall and Keane 2001). Long generation times mean that individual trees may be exposed to many threats throughout their lifetimes, and that populations will take a long time to recover from threats.

# 4.0 Situational Analysis

## 4.1 Biology

### 4.1.1 Growth and Reproduction

Whitebark pine and limber pine grow slowly in environmentally stressful native habitats. Slow growth restricts these species to habitats with limited competition from other species (Figure 1; Arno and Hoff 1990). Their distributions overlap in Alberta south of 52°N. Whitebark pine generally occurs at higher elevations but the species can be differentiated in the field only by their seed and pollen cones. Both species first produce cones around age 30, with consistent whitebark pine cone crops starting around age 70 (McCaughey and Tomback 2001) and age 50 for limber pine. Both are “masting” species, where large crops are produced at irregular intervals with few seeds in between (McCaughey and Tomback 2001; Peters and Gelderman 2011).

**Figure 1. Limber pine (left), whitebark pine (right).**

Clark’s nutcracker (Figure 2), a jay-sized corvid, is the exclusive seed disperser for whitebark pine (Lorenz *et al.* 2008) and is the primary disperser for limber pine (Benkman *et al.* 1984; Tomback and Linhart 1990). Seed is cached in unfavourable and favourable microsites for pine regeneration (Tomback 1982; Lorenz *et al.* 2011). Unretrieved seeds are the sole source of five-needle pine regeneration. The northern limit of whitebark pine appears to be influenced by nutcrackers, which are restricted to the northern limit of Douglas-fir, their only regional alternate food source between mast years when five-needle pine seeds are not available (Clason 2017). Where white pine blister rust infection levels and crown mortality are high, cone production declines (Barringer and Tomback 2009), attracting fewer nutcrackers (Tomback and Kendall 2001; McKinney and Tomback 2007; McKinney *et al.* 2009; Barringer *et al.* 2012), which in turn reduces five-needle pine dispersal and regeneration. Most studies of Clark's nutcracker population dynamics are from the US, and there is little specific data on Canadian populations, which could differ as limber and whitebark pine habitat and regeneration and stand conditions are different towards their northern limits. This is a knowledge gap as nutcracker population sizes, dispersal distances, and characteristics needed to support limber and whitebark pine recovery in Canada are unknown.

**Figure 2. Clark's nutcracker.**

### 4.1.2 Ecological Role

Compared to other species, whitebark and limber pine seeds have the highest ratio of nutrition to seed size, number and tree density, and provide a compact, rich food source for nearly 100 species of birds, small mammals and bears (Tomback and Kendall 2001). Other ecological roles of these pines include modifying the hydrology of alpine headwater streams through delaying and extending snowmelt, stabilizing slopes through root anchoring, treeline initiation and maintenance as pioneer species, and facilitation of succession in subalpine ecosystems as a climax species (Tomback *et al.* 2016). Limber pine seedlings are relatively drought tolerant, which allows them to establish in more arid locations than whitebark pine (Brunelle *et al.* 2008).

### 4.1.3 Genetics

Both species show individual tree and population variation in resistance to white pine blister rust (Sniezko *et al.* 2011, 2012; Liu *et al.* 2016). There are several types of heritable quantitative resistance in whitebark pine (Hoff *et al.* 1980, 2001; Sniezko *et al.* 2012). Limber pine has a dominant trait attributed to a major resistance gene (Schoettle *et al.* 2014), which occurs in southwestern Alberta (Sniezko *et al.* 2016). Several other five-needle pine species with similar resistance expression have related, but unique, genes (Schoettle *et al.* 2014).

Whitebark pine has relatively high genetic diversity within individuals and populations and relatively low differentiation between populations (Bruederle *et al.* 1998; Krakowski *et al.* 2003). It tolerates higher levels of inbreeding than do most pines (Hamrick and Godt 1990; Bower and Aitken 2008), with close relatives within the same clump reflecting nutcracker caching patterns (Furnier *et al.* 1987; Bruederle *et al.* 1998; Stuart-Smith 1998; Krakowski *et al.* 2003). Northern whitebark pine populations have low genetic differentiation (Richardson *et al* .2002; Liu *et al.* 2016) and could be considered one metapopulation based on allelic frequencies. Trade-offs have been expressed between rust resistance and cold hardiness, but populations from Yellowstone were the primary drivers of this observed pattern (Mahalovich *et al.* 2011, 2016). Selection for disease resistance should not create a genetic bottleneck, as quantitative resistance with numerous underlying mechanisms is widespread and present at varying frequencies in nearly all tested populations (Sniezko *et al.* 2011; R. Sniezko and M. Murray, unpublished data). Whitebark pine populations support sufficient genetic variation to yield improvement for traits such as growth, cold hardiness and disease resistance (Mahalovich *et al.* 2006; Bower and Aitken 2008), although there are few studies on material older than seedlings.

Limber pine has slightly higher diversity and differentiation among populations than does whitebark pine. North American populations group into three broad regions (Mitton *et al.* 2000): the northern Rocky Mountains subpopulation (including Alberta) had lower genetic diversity than did the Utah Rocky Mountain subpopulation, while the Basin and Range region had the highest diversity (Jørgensen *et al.* 2002). Adaptive traits in seedlings follow a moderately significant north-south cline from Alberta to New Mexico (Gass 2016). Similar to the case for whitebark pine, there is sufficient genetic variation in limber pine populations that selecting for disease resistance will not create a population bottleneck, and limber pine also has qualitative resistance identified in numerous stands (R. Sniezko, unpublished data).

## 4.2 Population Status

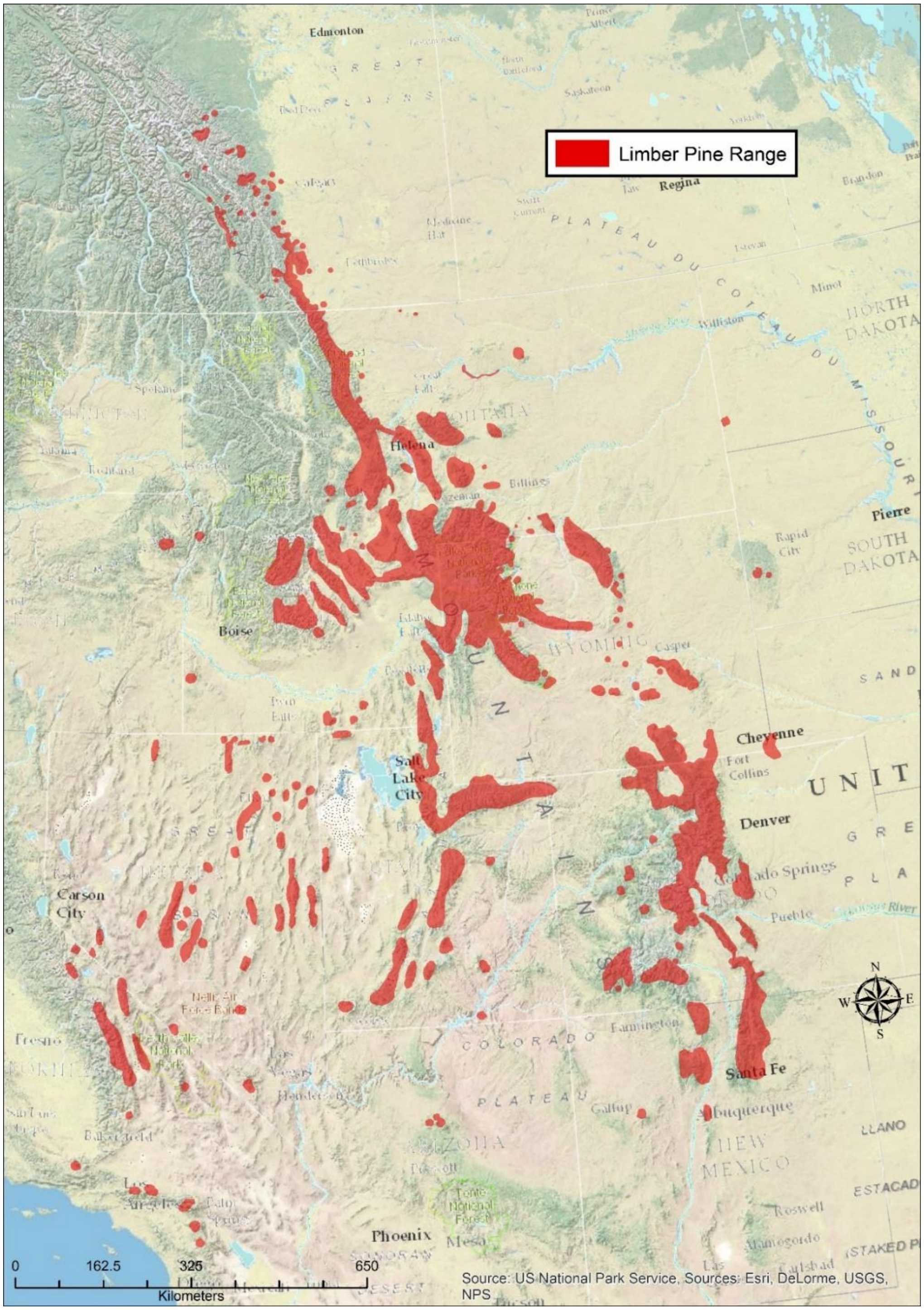
The 2010 population of whitebark pine in Alberta was estimated at between 28.9 and 187.8 million trees (COSEWIC 2010) based on a mean mature tree density estimate of 263 stems/ha

(Smith *et al.* 2008) and occupancy estimates between 1,099 and 7,148 km$^2$ (Alberta Sustainable Resource Development and Alberta Conservation Association 2007a). Since then, identified threats have reduced population estimates by up to 10% (Shepherd *et al.* 2018; Natural Resources Canada 2019), with more locally severe impacts in Jasper National Park caused by mountain pine beetle and in Waterton Lakes National Park caused by the 2017 Kenow wildfire. Limited inventory data and ongoing mortality add uncertainty. The estimated rate of whitebark pine population decline over 100 years is 78% for the Canadian Rockies, 97% for Waterton Lakes National Park, and 57% for the whole of Canada (COSEWIC 2010). These estimates assume no change in infection levels, status or recruitment, which is optimistic.

While the provincial range of limber pine is known (Figure 3), the species has limited inventory in Canada. Area of occupancy estimates for Alberta range from 16,000 km$^2$ (Alberta Sustainable Resource Development and Alberta Conservation Association 2007b) to 35,568 km$^2$ (COSEWIC 2014), with between 1.9 and 44 million mature trees in Alberta. Alberta limber pine populations are rapidly declining in the south from white pine blister rust (Figure 3; Smith *et al.* 2013), with trees exhibiting 37% mortality and 53% infection in 89 re-measured plots in 2014 (B. Shepherd, in prep.), aligned with a projected 66% decline over 100 years (COSEWIC 2014). The population in Waterton Lakes National Park was also reduced severely by the 2017 Kenow wildfire.

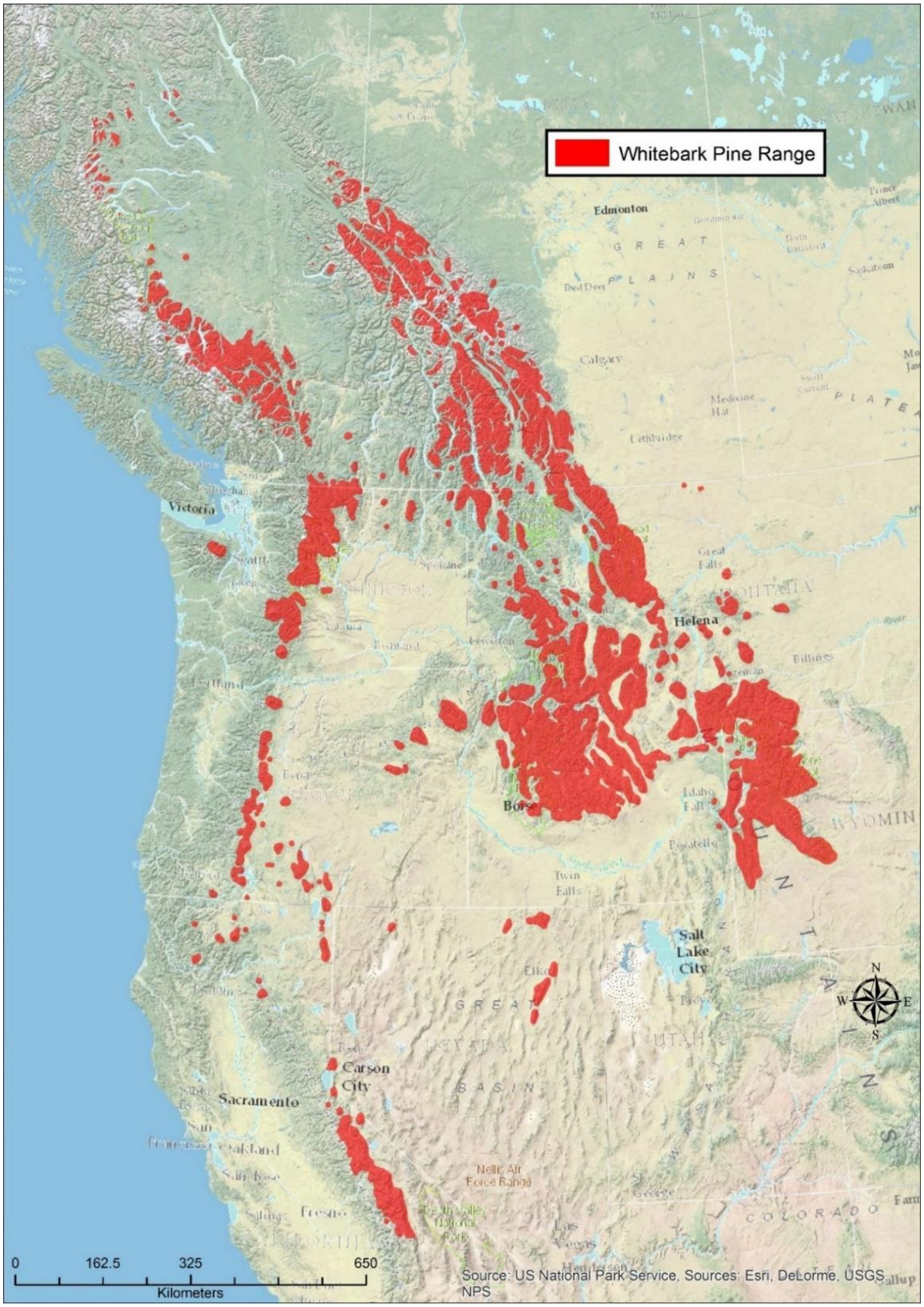
## 4.3 Distribution and Habitat

In Alberta, the northern limit of whitebark pine is in the Kakwa Wildland Provincial Park (Ogilvie 1990). It occurs over 100 km further north in BC. In Alberta, the distribution is generally continuous, becoming restricted to patches of suitable habitat in the Rocky Mountains south to Waterton Lakes National Park (Figure 4.), generally above 1800 m (Alberta Sustainable Resource Development and Alberta Conservation Association 2007a). Modelling indicated approximately



Source: US National Park Service, Sources: Esri, DeLorme, USGS, NPS

**Figure 3. Known range of limber pine in North America. Whitebark Pine Ecosystem Foundation 2014a.**



Source: US National Park Service, Sources: Esri, DeLorme, USGS, NPS

Figure 4. Known range of whitebark pine in North America. Whitebark Pine Ecosystem Foundation 2014b.

200,000 ha of suitable habitat in Alberta, excluding national parks (Krakowski *et al.* 2017), but it is not all currently occupied, and does not reflect marginal or disturbed habitats. Most of the Alberta range of whitebark pine is in protected areas (national parks and provincial protected areas), and there is a substantial population in the C5 Forest Management Unit. Approximately 15% of suitable habitat in the Alberta range occurs in national parks.

Limber pine ranges from 52°N near the Kootenay Plains in Alberta, extending south and west (Tomback and Achuff 2010). In Canada, 80 to 90% of the limber pine occurs in Alberta along the eastern slopes of the Rocky Mountains (Figure 3), with isolated pockets in southeastern BC (Alberta Sustainable Resource Development and Alberta Conservation Association 2007b). The northern Alberta populations show continuous recruitment over 100 years, including rapid recruitment in populations killed by fire and isolated from a seed source by several kilometres (Webster and Johnson 2000). Models estimate that approximately 27,000 ha of suitable habitat occurs in Alberta, excluding national parks (Krakowski *et al.* 2017), although not all of it is currently occupied, and the estimate excludes marginal and disturbed habitats. Approximately 10% of suitable habitat in the Alberta range occurs in national parks.

## 4.4 Threats

Four main factors affect the survival of whitebark pine: white pine blister rust, mountain pine beetle, altered fire regimes (exclusion promotes successional replacement, and catastrophic wildfires cause direct mortality) and climate change (Tomback *et al.* 2001; Keane *et al.* 2017a). Two main threats affect the survival of limber pine: white pine blister rust and altered fire regimes and, to a lesser extent, direct impacts from land use. The severity of other factors affecting limber pine health varies by area (Table 1 reflects IUCN threat assessment categories and Open

Standards methods; see Appendix 1 for detailed threat assessments for each species, with rationale).

Although a century is a conservative estimate of the time needed for recovery to be successful for whitebark and limber pine, a 10-year period is considered relevant for monitoring, reassessment and adaptive management. Threat impacts were based on severity, extent and timing.

**Table 1. Threats ranking for Alberta for 100-year time frame. See Appendix 1 for detailed threat assessments for each species.**

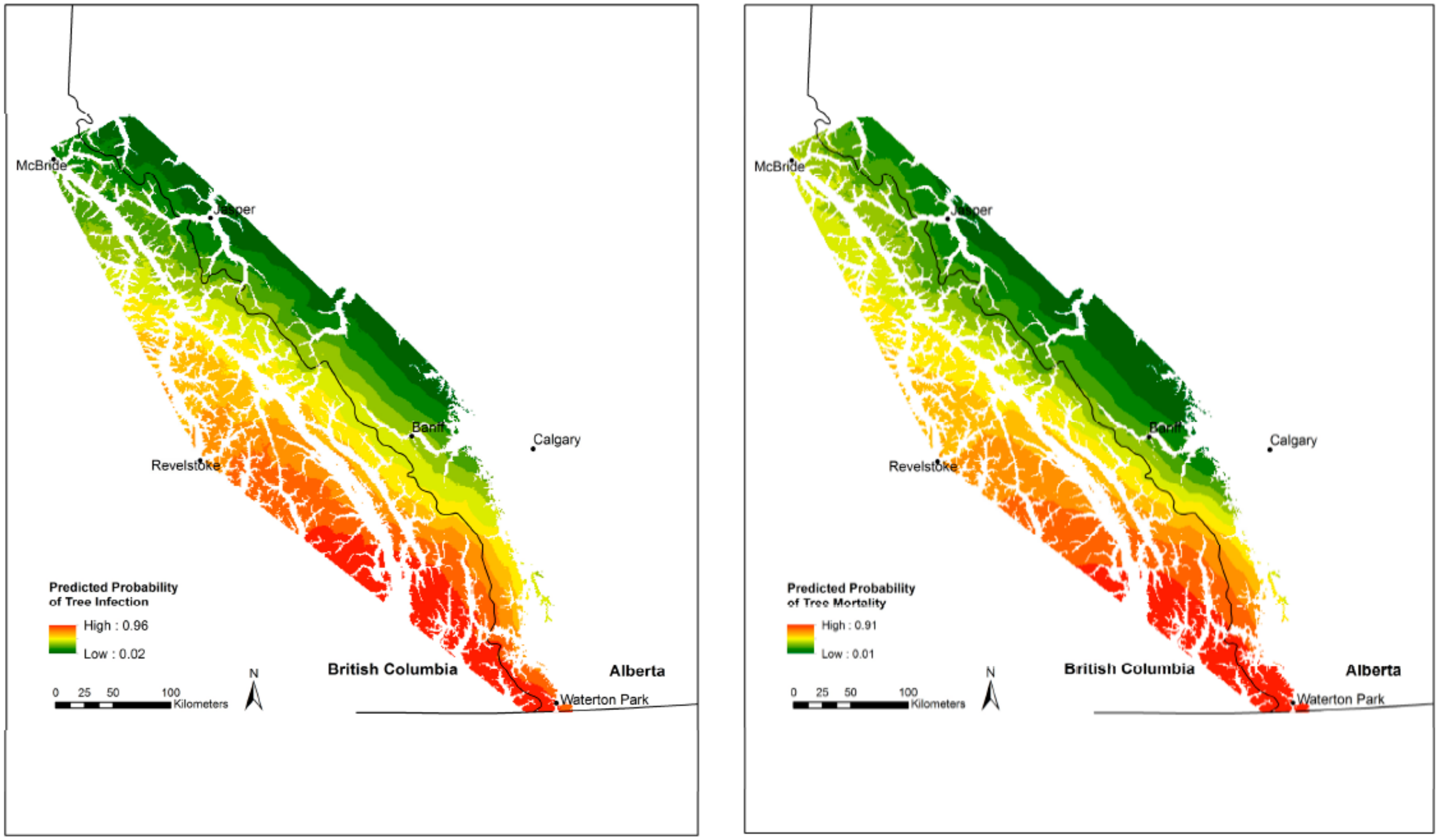
| Threat | Limber Pine | Whitebark Pine | Comments |
|---|---|---|---|
| White pine blister rust | Very High | Very High | Natural resistance levels are very low |
| Fire effects | Medium | Medium | |
| • Fire suppression | Medium | Medium | Can cause habitat alteration and successional change reducing regeneration |
| • Fire regime outside the range of historical variability | Medium | Medium | Severe fires outside range of historical variability cause mortality |
| Mountain pine beetle | Low | Medium | Threat increases during severe outbreaks; impact scaled down in recent years; affects mature trees |
| Climate change | Medium-Low | Medium | Habitat shifting/alteration, droughts and temperature change affect habitat availability, increase competition with other species and reduce regeneration |
| Land use | Medium | Medium-Low | |
| • Mining/mineral exploration | Medium | Medium-Low | Potential for coal development within range of both species |
| • Grazing | Low | NA | Mostly trampling of regeneration; some breaking of cone-bearing branches, Only a threat for limber pine |
| Summary rating | Very High | Very High | Threat from white pine blister rust greatly outweighs other threats, although other threats add to cumulative threat impact |

### 4.4.1 White Pine Blister Rust

All North American five-needle pines are susceptible to the non-native fungal pathogen *Cronartium ribicola*, which causes the disease white pine blister rust. Its complex life cycle requires alternation between a five-needle pine and another host plant, typically of the genus *Ribes* (McDonald and Hoff 2001), but also *Pedicularis* and *Castilleja* (McDonald *et al.* 2006). Seasonal temperature and humidity drive site rust hazard and infection (Geils *et al.* 2010). Most infected trees die, as infection spreads from needles down to the main stem at which point the tree is girdled. A major negative effect of rust infection is that crown branch mortality typically occurs before the tree dies (McDonald and Hoff 2001), significantly impairing the important ecological functions of cone production and seed dispersal (Keane *et al.* 1994).

Blister rust was first reported in Alberta on limber pine in 1952 (Bourchier 1952). By 1958, 75% of limber pines in the Waterton area were infected, increasing to 100% by 1960, with mortality beginning to skyrocket (Gautreau 1963). By 1996, blister rust extended throughout the Alberta range of whitebark pine (Stuart-Smith 1998), and it continues to increase northward and in severity (Kendall *et al.* 1996; Smith *et al.* 2013; Shepherd *et al.* 2018). By 2014, limber pine had similar regional infection and mortality patterns as whitebark pine; infection rates increased by an average of 2.4% per year over the past 10 years, with 92% of plots infected (B. Shepherd, in prep.). Plots in Banff had higher increase rates because Waterton already had extremely high infection and mortality. Plots in the David Thompson region and near Banff have low rust relative to plots to the north and south. The cause of this pattern is not confirmed but could be related to high wind and arid habitats being generally unfavourable for the pathogen.

The mean infection probability level for the combined Canadian Rockies and Alberta whitebark pine transects is 50% in mid latitudes and 80% in the south, increasing with tree diameter; the mean mortality level is 61% in the south and 11% in the north, an increase of 10% over 10 years (Shepherd *et al.* 2018; Figure 5). Seedlings showed similar patterns but with lower infection levels. Some plots have 100% infection and 90% mortality (Smith *et al.* 2008). Between 2003 and 2014, infection levels increased far more in the south than in the north. Blister rust has rendered some stands functionally extinct until restoration increases cone production, which will take decades.



(a)

(b)

**Figure 5. The predicted probability of tree (10-cm diameter) white pine blister rust (a) infection and (b) mortality in whitebark pine in the Canadian Rockies. From Shepherd *et al.* (2018).**

### 4.4.2 Fire

Fire regimes in whitebark pine habitat are complex and highly variable (Campbell *et al.* 2011), with different results reported in Canadian and US studies. Mixed-severity fire regimes appear to be the most beneficial for whitebark pine (Murray 2007; Campbell *et al.* 2011), and fire may not be as tightly linked to whitebark pine regeneration in northern ecosystems as it is in the southern Rockies (Moody 2006; Gelderman *et al.* 2016; Drummond 2018; J. Krakowski, unpublished data). Fire exclusion is typically cited as a major factor in the decline of whitebark pine, because fire resets the successional clock, creates openings for regeneration, and removes competing vegetation (Arno 2001; Sala *et al.* 2001; Keane *et al.* 2012). Note that fire exclusion policies have rarely been in place over one or more entire stand-replacing subalpine fire return intervals, so the only empirical testing of their impacts has been during the past century (Baker 2009; Larson and Kipmueller 2012). Ongoing suppression of low-intensity fire, which whitebark pine usually survives but shade-tolerant, thin-barked competing species do not, can increase the latter species at the expense of whitebark pine (Murray *et al.* 1998; Kendall and Keane 2001). Arno (2001) estimated that successional replacement has reduced whitebark pine habitat area by 50% in western Montana by moving its lower elevational limit upslope by 240 m. Fire exclusion also leads to fuel buildup, increasing the severity and frequency of catastrophic fires that then kill mature trees, regeneration and mycorrhizae (Keane *et al.* 2017a). Both reduced frequency and increased severity of wildfire are symptoms of fire regimes outside of the range of historical variability.

Limber pine also experiences fire regimes that vary spatially across its range (Coop and Schoettle 2009). On open rocky sites with little fuel, fire is rare and not important for ecosystem dynamics. On productive sites, limber pine may depend on fire to remove competition and open up sites for seed caching by nutcrackers. Long fire return intervals facilitate limber pine expansion into grasslands and increase stand density (Keane *et al.* 2002; Brown and Schoettle 2008); however, they may also lead to the domination of limber pine ecosystems by Douglas-fir (Stockdale 2017). Nutcrackers enable rapid recolonization of extirpated populations after fire (Webster and Johnson 2000). Lorenz *et al.* (2008) found no supporting data on nutcracker preference for burned areas to cache seeds. Dawe (2019) found far more regeneration in unburnt than in burnt sites in Alberta. Fire suppression has altered fire regimes and ecosystem characteristics and distribution in Alberta foothills and subalpine habitats (Stockdale 2017), and less recently burned limber pine habitat is available than was the case in the last century (Luckman and Kavanaugh 2000). Long-term stability of limber pine woodland habitats is impaired by fire suppression, which promotes their replacement by other, more shade-tolerant species (Means 2011; Stockdale 2017).

### 4.4.3 Climate Change

Whitebark pine grows at treeline, with its lower elevational limit determined by competition (Arno and Hoff 1990; Callaway 1998; Campbell and Antos 2003). Warming will enable faster-growing and more shade-tolerant co-occurring species to outcompete whitebark pine, resulting in loss of habitat with little or no anticipated new habitat becoming available (Hansen *et al.* 2016; Keane *et al.* 2018). The northern range of whitebark pine is limited by dispersal: there is ample suitable habitat supporting germination and survival north of the range limit of whitebark pine (McLane and Aitken 2012; Clason 2017), but without established nutcracker populations sustained by their alternate food sources, these areas will not be viable whitebark pine habitat. Suitable northerly habitats will also diminish over time with warming, due largely to competition and dispersal limitations, retracting populations to core areas away from the northern periphery (Clason 2017).

Limber pine habitat area and abundance at broad scales appear relatively insensitive to predicted climate change because of high levels of variability and strong influences on the species' success by local site factors. It is able to reproduce and survive in very droughty habitats where other trees cannot. Based on regeneration data, populations are predicted to move upslope (Monahan *et al.* 2013). Lower elevation ravines appear to be functioning as limber pine climate refugia along the species' southern range limits (Millar *et al.* 2018).

### 4.4.4 Land Use

Both direct mortality (removal of trees) and indirect mortality (e.g., activity that alters competition) associated with industrial and recreational land use (which is governed by policy and legislation) affect both species (Table 1). In Canada, these species currently lack legal protection on provincial lands outside of parks, and whitebark pine may be harvested either inadvertently or during forestry operations with permission from Alberta Forestry and Rural Economic Development when it occurs intermingled with target species and it is not considered practicable to avoid cutting it. Land use impacts may have limited extent, but can have high local duration and severity. Mining/mineral exploration has a high, localized impact associated with the footprint and associated linear features (access, transmission lines) that endures until reclamation is deemed complete.

Expansion of coal mining in the foothills is a threat to both whitebark and limber pine in Alberta's eastern slopes because of overlap with bituminous coal. In June 2020, the Alberta Government rescinded the 1976 "A Coal Development Policy for Alberta". The coal policy was reinstated in full in February 2021, pending public engagement about the province's long-term approach to coal development. The threat score for coal development depends on the direction the policy ends up taking but with current interest and intended activities, coal activities are a plausible threat.

Careful planning, accurate inventory and diligent field assessment by individuals with specific training and field expertise in identifying blister rust and in restoration of these species during project pre-planning and layout can avoid, minimize or mitigate impacts, but if the activity is widespread, impacts will be unavoidable. When human activity is proposed in whitebark or limber pine habitat, appropriate measures should be determined on a case-by-case basis, based on advice from a qualified expert and taking into account the timeframe and scope of the disturbance in relation to recovery efforts.

### 4.4.5 Mountain Pine Beetle

The mountain pine beetle is a native bark beetle of western North American pine forests, including whitebark and limber pine habitats (Brunelle *et al.* 2008). It has recently expanded its range northwards in pine host forests in response to warmer temperatures (Safranyik *et al.* 2010). The beetles tunnel through the bark into the phloem to reproduce, then larvae consume the phloem until they emerge in mid-summer. They infect the tree with fungi that block moisture transport through the xylem (Safranyik and Carroll 2006; Rice *et al.* 2007; Six and Wingfield 2011; Hubbard *et al.* 2013). Mass attacks of large numbers of beetles stress and can entirely girdle mature trees, which die the same or the next year.

Limber pine’s thick phloem and bark enable higher mountain pine beetle overwinter survival and Outbreaks occurred in Alberta in the mid-1940s and from the late 1970s to the early 1980s (Miyagawa 1995), causing significant limber pine mortality north of Crowsnest Pass into the Porcupine Hills, when around 40,000 limber pine were removed for control efforts (Alberta Forestry, Lands and Wildlife 1986). Contemporary infestations in western North America are causing historically unprecedented mortality (Safranyik *et al.* 2010; Bentz *et al.* 2011). Warming temperatures have increased overwinter survival of beetles at high elevations, enabling a one-year life cycle compared to the normal two or three years in colder areas (Amman 1973; Logan *et al.* 2010). Mountain pine beetles in Alberta are monitored annually with control measures taken at the individual tree, tree cluster and landscape levels. Survey efforts generally focus on merchantable timber stands, but some current attacks are in or close to whitebark and limber pine stands (Figure 6.). Ample evidence indicates that the warming climate is facilitating the spread and persistence of mountain pine beetle into higher elevations and more northerly latitudes (Carroll *et al.* 2004).

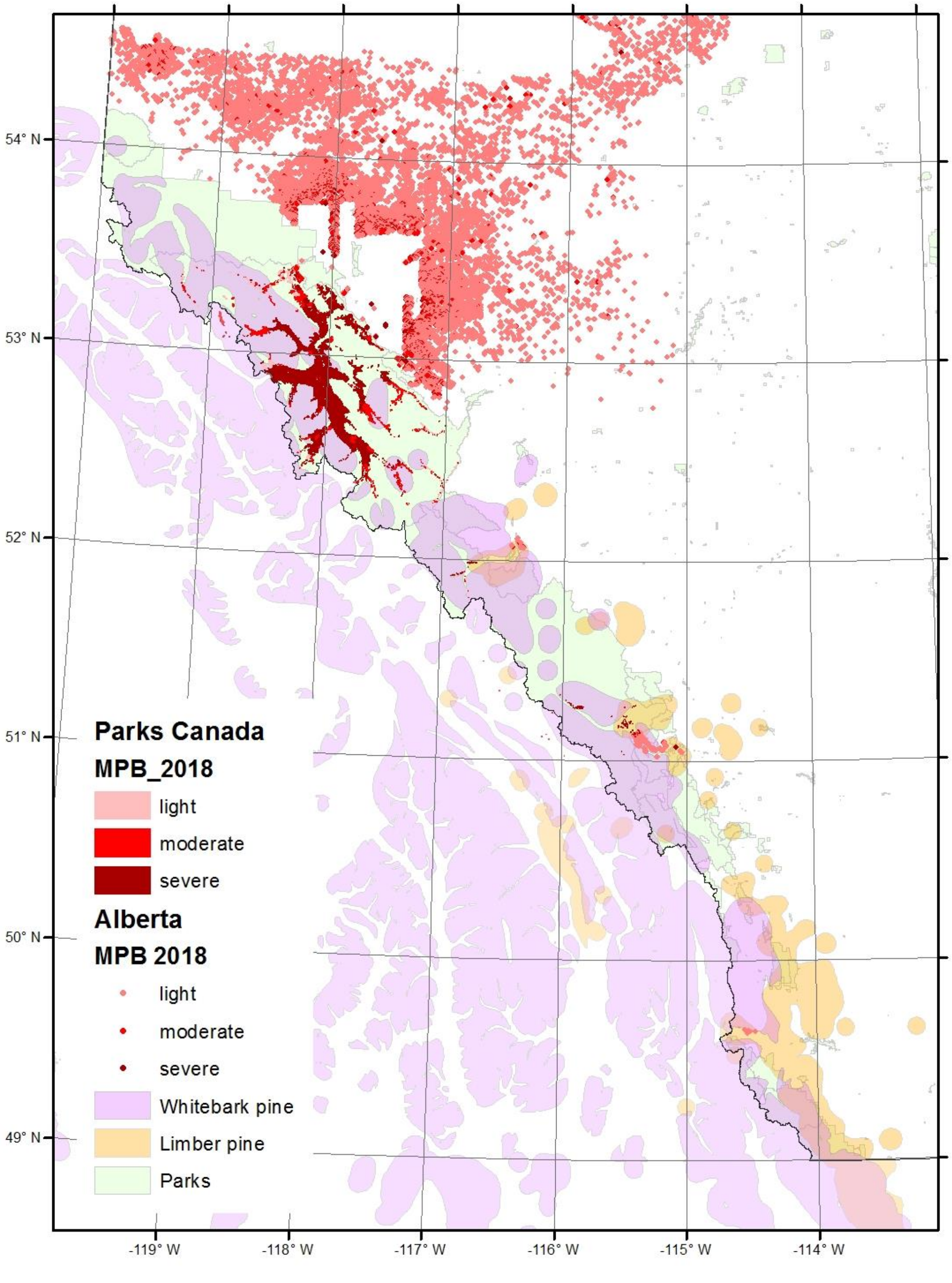


**Figure 6. Alberta 2018 aerial mountain pine beetle survey records overlapping with whitebark pine (blue) and limber pine (red). Note that not all areas are surveyed each year.**

Whitebark pine trees infected by white pine blister rust may be preferentially attacked by mountain pine beetle, and infection may predispose smaller trees to mountain pine beetle when they reach cone-bearing age (Six and Adams 2007; Bockino and Tinker 2012; Jules *et al.* 2016). The strong preference of mountain pine beetles for larger trees disproportionately reduces stand seed production (Kendall and Keane 2001) — especially when beetles kill rare, valuable mature trees that are resistant to white pine blister rust.

### 4.4.6 Other Threats

Cattle grazing impedes limber pine seedling establishment but is not an issue for whitebark pine. Other land uses such as ski infrastructure and mountain recreational development may remove whitebark pine trees, as do rights-of-way for powerlines, pipelines and resource roads.

Engraver beetles are typically secondary attackers that build up populations after mountain pine beetle infestations, and in abundant slash (Waring and Six 2005; Keane and Parsons 2010). They occasionally attack healthy whitebark and limber pine (J. Krakowski and M. Murray, unpubl. obs.), but rarely kill healthy trees. Occurrences may increase in severity or extent if other stressors increase.

Successive very dry summers have caused drought mortality in some mature trees and regeneration in localized areas, particularly in limber pine. This could increase in extent with climate change. Surviving trees have reduced vigour, dead crown foliage and aborted cones (J. Krakowski, unpubl. data).

# 5.0 Recovery Goal and Objectives

## 5.1 Biological and Technical Feasibility of Recovery

Maintaining and recovering whitebark and limber pine in Alberta is biologically feasible, given current and anticipated future environmental conditions, and knowledge of restoration methods. However, the time scale for success is on the order of a century. Periodic re-evaluation and adaptive management of targets and success measures is needed. It may not be feasible to maintain and restore viable populations across the full extent of the current range given the potential impacts of climate change over the longer term. Core habitat across the range, including that of most or all Alberta populations, is likely to sustain viable populations, and climate refugia can be identified and managed for connectivity and seed source viability, mitigating the uncertainty regarding future range limits. Without management intervention, genetic rescue as a result of seed dispersal from adjacent jurisdictions is unlikely as the poor health of these populations has reduced cone production, which deters Clark's nutcrackers from visiting (Tomback and Kendall 2001; Siepielski and Benkman 2007; McKinney and Tomback 2007; McKinney *et al.* 2009; Barringer *et al.* 2012) and reduces nutcracker population viability (Schaming 2015).

Sufficient information exists to support and direct recovery in Alberta. Technical feasibility is delineated in the abundance of guidelines and restoration strategies for high-elevation five-needle pines (Wilson and Stuart-Smith 2002; Schoettle 2004; Schoettle and Sniezko 2007; Burns *et al.* 2008; Shoal *et al.* 2008; Pigott *et al.* 2015; Keane *et al.* 2012, 2017a; Environment and Climate Change Canada 2017). Information is available on collecting cones for seed (Ward *et al.* 2006), growing seedlings (Burr *et al.* 2001; Overton *et al.* 2016), planting seedlings (Scott and MacCaughey 2006; Coop and Schoettle 2009), seed transfer (Bower and Aitken 2008; Mahalovich 2015; Krakowski 2018), enhancing resistance to white pine blister rust (Hoff *et al.* 2001; Burns *et al.* 2008; Sniezko and Koch 2017), protecting high value trees from mountain pine beetle attack (Gillette *et al.* 2014; B. Shepherd, unpubl. data), and use of fire in five-needle pine ecosystems, primarily in the US (Keane and Arno 2001; Arno and Fiedler 2005; Keane *et al.* 2017b).

Successful whitebark and limber pine recovery requires an ongoing commitment and sustaining partnerships across agencies and jurisdictions. Establishing a diverse, durable base of adapted disease-tolerant and/or resistant seed sources, monitoring of threat impacts and treatment results, and ongoing implementation of recovery actions are all necessary. Supporting actions include planting seedlings to increase the frequency of rust resistance across the landscape, habitat improvements, mountain pine beetle impact mitigation, establishing seed orchards to support a cost-effective supply of rust-resistant, well-adapted seedlings, and increasing capacity to grow and plant seedlings. Communicating the species' status, recovery needs and best practices is key to preventing and minimizing impacts of proposed development and land management activities, filling knowledge gaps, implementing priority actions (in terms of both the risk posed by the threat that the action addresses, and the efficacy of the proposed action), and directing limited resources to where they are most needed. Target groups include land managers, indigenous communities whose territories overlap suitable habitat, regulators, industry, user groups, non-governmental agencies including the Whitebark Pine Ecosystem Foundation of Canada, and other stakeholders operating in suitable habitat.

A further demonstration of feasibility is the successful initiatives in the US, where several thousand whitebark pine and several hundred limber pine plus trees have been screened for rust resistance, are protected from mountain pine beetle, and provide seed for rust-resistant seedlings as per range-wide species-specific seed transfer guidelines. The United States Department of Agriculture, Forest Service — Forest Health Protection program has leveraged millions of dollars to date through the Whitebark Pine Restoration Program, yielding thousands of planted hectares, four seed orchards, and numerous thinning and prescribed fire programs. Most programs are carried out by national parks, national forests, and state and tribal government agencies. A model of success is provided by the Greater Yellowstone Coordinating Committee — Whitebark Pine Subcommittee (https://www.nps.gov/articles/series.htm?id=F5A9B723-EEDA-829C-F5685A6C7203F1A7). This multi-agency group, led by a chair and co-chair, coordinates priorities, plans and implementation to support recovery of whitebark pine across the diverse jurisdictions encompassing the Greater Yellowstone Area. They support research, share information, develop standards and best practices, have developed a seed orchard to supply tested elite seedlings for restoration with a complementary clone bank, conduct monitoring, and track and report activities.

## 5.2 Recovery Goal, Objectives and Indicators

The Alberta recovery goal for whitebark pine and limber pine is to have at least one self-sustaining metapopulation per species per management unit of sufficient size, composition and distribution to sustain Clark's nutcracker populations within their historical range and support adaptation in their projected future range. Each species has two management units, split north and south of Highway 1 to reflect blister rust infection rates.

Because these species in Alberta tend to grow in stands that are separated but share genetic material through bird dispersal, a metapopulation approach is appropriate. As populations fluctuate or decline because of natural disturbance, environmental stress or threats, rescue may naturally occur by seed dispersal from nearby stands. If thresholds for connectivity and population size within and between stands are not met, then stands may be extirpated and require human activity for recovery. To sustain whitebark and limber pine populations across their ranges, the exact number of trees needed and their required distribution is not known, but the thresholds identified in published studies support recovery targets defining characteristics of a successful metapopulation containing at least 2 $m^2$/ha of mature trees, at least 200 stems/ha of regeneration, within 2 km from adjacent stands with these characteristics for proximal dispersal but as far as 20 km from adjacent stands with these characteristics for long-distance dispersal, in the general vicinity of alternate food sources such as Douglas fir, and containing suitable habitat for regeneration and survival (i.e., with limited herbaceous, shrub, and tree competition, well-drained soils, occurring at suitable elevations and substrates).

Condition thresholds available for each target, and the current status of each target, were estimated or quantified where current data were available (Table 2).

**Table 2. Condition monitoring measures and current status of five-needle pines (5NP).**

| Indicator | Target | | Unit | Condition | | | |
|---|---|---|---|---|---|---|---|
| | Short-term | Long-term | | Poor | Fair | Good | Status |
| 1.1 Hectares of habitat restored | 2020: 100 ha<br>2025: 1000 ha | | ha | <100 | 100-700 | >700 | Poor |
| 1.2 Rate of subpopulation decline or increase | | 2050: <50% of sub-populations declining<br>2050: ≥10% increasing | % sub-populations increasing vs declining | >50 | 25-50 | <25 | Poor |
| 1.3 Live mature 5NP basal area | | 2100: ≥50% of stands in suitable habitat have ≥2 $m^2$/ha live mature 5NP BA | % stands | <25 | 25-50 | >50 | Poor (south) |
| | | | | | | | Fair (north) |
| 2.1 Metapopulation size per unit | 2030: ≥50% of stands have ≥200 stems/ha regeneration, | | % stands | <25 | 25-50 | >50 | Fair (south) |
| | | | | | | | Good* (north) |
| 2.1 Metapopulation size per unit+ | 2030: ≥30% of stands have ≥2 $m^2$/ha live mature 5NP BA | | % stands | <10 | 10-30 | >30 | Fair (south) |
| | | | | | | | Good (north) |
| 2.2 Metapopulation connectivity per unit | | 2080: ≥50% of 5NP stands ≤2 km from adjacent stand<br>2080: ≥20% of stands ≤20 km from adjacent stand | % stands | >30 | 30-50 | >50 | Fair (south) |
| | | | | | | | Good (north) |

*Blister rust infection rates are trending upward in northern populations, so the status could decline as a result in the future.

**Objective 1:** By 2100, the rate of increase in the metapopulation of five-needle pine trees with elevated disease tolerance or resistance in each management unit is greater than the rate of decline caused by blister rust.

**Rationale:** The slow growth and maturation of these species means a seed planted now will grow into a tree producing a reliable cone crop in 80 (limber) to 100 years (whitebark), which must be dispersed and planted by Clark’s nutcracker. One tree generation exceeds land use planning timelines and several human generations. Nutcracker visitation is likely when live mature five-needle pine basal area exceeds 2.0 $m^2$/ha. Seed used for restoration where blister rust hazard is significant must originate from plus trees with elevated levels of disease tolerance or resistance so seedlings can survive the decades needed to reproduce. Complete resistance genes are rare in limber pine and absent in whitebark pine; varying degrees of tolerance (multigenic partial resistance) occur, rarely, in both species. Where rust infection is lower, landscape-level approaches may be more appropriate to promote regeneration and reduce decline related to other threats and their interactions.

**Indicator 1.1:** Hectares of habitat restored.

**Target:** by 2020, at least 100 ha restored cumulatively; by 2025, at least 1000 ha restored cumulatively.

**Method note:** Methods published for seed collection, handling, germination, seedling production, planting, silvicultural treatments (Keane *et al.* 2012 and references therein).

**Indicator 1.2:** Rate of subpopulation decline or increase.

**Target:** by 2050, fewer than 50% of monitored stands are declining and at least 10% are increasing; by 2080, fewer than 25% of stands are declining and at least 30% are increasing.

**Method note:** Tomback *et al.* 2005.

**Indicator 1.3:** Basal area of live mature (reproductive) five-needle pines.

**Target:** by 2100, basal area of live mature five-needle pines of at least 50% of all monitored stands exceeds 2 $m^2$/ha.

**Method note:** Tomback *et al.* 2005; Barringer *et al.* 2012.

**Objective 2:** By 2120, at least one self-sustaining metapopulation of each five-needle pine species is established north and south of Highway 1.

**Rationale:** High rates of gene flow support limited differentiation across broad areas. The high infection rates south of Highway 1 support a focus on stand-level strategies for recovery, while lower infection rates to the north support more landscape-level approaches. Monitoring results may trigger changes to this approach in the future. Mean dispersal distances by nutcrackers are around 2 km, but distances of up to 32 km have been recorded; nutcrackers also move and re-cache seeds.

**Indicator 2.1:** Metapopulation size per unit.

**Target:** by 2030, at least 50% of monitored stands have at least 200 stems per hectare of regeneration present and at least 30% of stands have at least 2 $m^2$/ha mature 5NP basal area. By 2100, at least 80% of stands have at least 200 stems per hectare of regeneration present and at least 50% of stands have 2 $m^2$/ha mature 5NP basal area.

**Method note:** Tomback *et al.* 2005; Barringer *et al.* 2012.

**Indicator 2.2:** Metapopulation connectivity per unit.

**Target:** by 2080, at least 50% of 5NP stands are within 2 km of at least one adjacent stand and 20% of stands are within 20 km of at least one adjacent stand.

**Method notes:** Vander Wall and Balda 1977; Lorenz *et al.* 2011.

# 6.0 Habitat Needed to Support Recovery

Habitat is not currently considered limiting to whitebark or limber pine recovery. Habitat is abundant and much of it lies within protected areas where anthropogenic disturbance is less common or widespread, connectivity generally is good and similar to historical patterns, and occupancy is, or has the potential to be, close to historical numbers across many parts of the historical range. Primary threats to the species do not affect the quality or quantity of the habitat to support recovery per se. Potential impacts from development are likely to impact only a small area and number of trees. While the most important factor is to avoid damaging or otherwise negatively affecting plus trees, actions to avoid, minimize and mitigate potential impacts should follow available best practices.

Future habitat quality, in terms of climatic suitability and site characteristics needed for recovery, should be considered given the slow growth, long lifespans and large variability affecting occupancy and persistence of both species. High infection rates and mortality levels in southern populations, and increasing infection rates in the north, support delineating all currently occupied habitat and predicted future habitat as important to support recovery. Climate change will have complex and varying effects on habitat suitability for these species. Scale is important to establishment, persistence, and range limits. Competition from other tree and grass species is likely to reduce habitat suitability in the lower elevations, while declining area available to colonize unvegetated alpine areas above current stands may reduce net future habitat area within the current range. Migration of most temperate tree species lags behind the migration rate of their respective climate envelopes. Climate refugia are typically characterized by complex terrain at varying spatial scales, which describes virtually all of the habitat in Alberta for whitebark and limber pine. Projections suggest with moderate certainty but considerable variability, that slightly moister growing seasons and deeper snowpacks mitigate drought risks at the eastern limit of the species' ranges in Alberta. This complex interplay makes it difficult to forecast habitat and climate relations for a specific area, which can be mitigated by ensuring broad areas of habitat containing sufficient topographic complexity and population densities and sizes are maintained and restored.

The occupied habitat of whitebark pine has diminished over the past several decades, although the range is unchanged. COSEWIC (2010) estimated 15.7% of the Canadian range was occupied, which can reasonably be extrapolated to Alberta. Occupancy for both species is patchy. As nearly all of the Canadian range of limber pine is in Alberta, this plan would have essentially the same scope and actions as a federal recovery strategy for that species.

# 7.0 Recovery Strategies and Actions

This section describes the strategies, actions, and progress measures to achieve the recovery goal and objectives. Priorities are in Section 8. Interim benchmarks are established to evaluate progress over the long time frame needed to achieve recovery.

**Strategy 1:** Maximize the frequency of disease-resistant trees in five-needle pine habitat in order to reverse the decline caused by white pine blister rust, supported by:

**Strategy 1.1:** Identify, protect and test plus trees.

**Rationale:** Plus trees must be identified by surveying and monitoring stands with high levels of blister rust. Seed for restoration planting needs to come from rare plus trees with increased disease resistance, or seedlings will die before reproducing. Testing is needed to confirm heritable resistance — not all plus trees prove to be resistant ("elite") trees. Plus trees must be protected from threats through spatial data sharing and planning (e.g., mountain pine beetle protection, fire protection, development avoidance). Currently, metapopulations for both species south of Highway 1 and some stands north of Highway 1 have high enough infection rates to select plus trees. At least 480 plus trees per species are required to sustain long-term diversity (2 seed zones x 20 trees x 3 seedlots x ~4 plus trees selected per confirmed elite tree). Actual numbers depend on screening results.

In the Alberta provincial recovery program to date, over 200 limber pine and 50 whitebark pine plus trees have been identified and sent for screening, subject to seed and funding availability. Plus trees are monitored for health and cone production, and protected from mountain pine beetle, fire or development using spatial information sharing and verbenone. Until a tested (elite) parent tree population is available, collecting seeds from plus trees (i.e., uninfected mature trees within heavily infected stands) is the next best strategy, one which is being implemented in southwestern Alberta where pine blister rust is high. Restoration in Alberta includes planting plus tree seedlings and thinning competing species in highly infected, accessible stands.

A best practices 2-pager consistent with the mitigation hierarchy is available for operational implementation from the recovery team to support industry operating in whitebark and limber pine habitat. It emphasizes avoiding impacts to plus trees, and other 5-needle pine trees, and provides options to minimize and mitigate impacts where unavoidable. When assessing the best approach to avoiding/mitigating impacts, consideration should be given to the timeframe of the impact in relation to proposed mitigation. Contact information for the recovery team to obtain more information and consolidate data is also provided (goa.endangeredpine@gov.ab.ca).

**Desired outcome:** By 2030, three operational seedlots are available for restoration, each composed of 20 unrelated elite trees, for each approved seed zone, per species, in numbers sufficient to fulfill planting goals.

**Progress measures:**

1. Number of plus trees selected
2. Number of plus trees tested
3. Mean increase in disease tolerance/resistance per seed zone and species
4. % plus trees protected from anticipated mountain pine beetle damage

**Recovery actions:**

1. Select plus trees in highly infected stands
2. Collect seeds
3. Screen plus trees using accepted methods
4. Based on mountain pine beetle and fire hazard and development applications, protect plus trees
5. Develop and provide best practices for operations in five-needle pine habitat

**Strategy 1.2:** Develop at least one seed orchard for each species sufficient to supply seed to meet restoration needs.

**Rationale:** Seed for restoration planting must come from trees with increased disease resistance. Collecting seed and protecting parent trees in the field is hazardous, expensive and time consuming. Seed supply is maximized by establishing at least one seed orchard per seed zone per species, containing grafted copies of elite and plus trees in a secure site conducive to management and seed production, with minimal pollen contamination from wild unselected trees. The orchard is also an ex situ genetic conservation reserve duplicating the rare wild genotypes, until resources permit establishing additional orchards and/or clone banks. To reduce risk exposure, multiple orchards per seed zone are recommended. The orchard may be managed to enhance early seed production; grafts are physiologically older than seedlings so they produce pollen and cones decades earlier. Because Alberta’s five-needle pines are distributed across land administered by numerous agencies, continuing and augmenting existing collaborations are key to sharing of resources and genotypes, and minimizing costs.

Consistent with the successful United States Department of Agriculture, Forest Service, Intermountain Region genetics program for whitebark pine (Mahalovich 2015), the Alberta recovery goal for both species is to produce three operational seedlots per seed zone, each comprising 20 unrelated tested rust-resistant (elite) parent trees. In order to secure a reliable supply of resistant, well-adapted seed from a secure, accessible location, a medium-term goal of the recovery plan is to establish at least one seed orchard per species per seed zone containing resistant genotypes to fulfill the goal. Multiple sites are desirable given uncertainty related to cone and pollen productivity, seed viability and potential fire damage.

In BC, over 200 whitebark pine plus trees have been submitted to the provincial screening program developed at Kalamalka Forestry Centre, which has generously included some Alberta selections with in-kind support from Alberta. The BC Forest Genetics Council supported a series of whitebark pine provenance trials and gene conservation seed collections, including the establishment of one test site in Alberta. This test site is planted beside a limber pine provenance trial of the latitudinal range of Rocky Mountain sources established by the United States Department of Agriculture, Forest Service and University of BC. Alberta also provides training and technical expertise, and shares genetic resources with BC, Parks Canada, the United States Department of Agriculture, Forest Service, and other partners.

**Desired outcome:** By 2030, at least one seed orchard per species is established and capable of producing three operational seedlots of 20 unrelated, tested resistant ("elite") parent trees for each approved seed zone, per species, with enough ramets (copies) of each tree to meet restoration seed needs for Alberta.

**Progress measures:**

1. Number of candidate sites selected and reviewed
2. Number of rootstock plants produced for grafting
3. Number of grafts completed at grafting facility
4. Number of grafts planted in orchard(s)

**Recovery actions:**

1. Clarify agency roles and responsibilities
2. Assess seed and seed orchard needs
3. Secure and prepare suitable sites, ideally multiple sites per species and seed zone (cleared, fenced, secured if required, etc.)

4. Collect and graft scions (branch cuttings) from plus trees onto rootstock
5. Establish grafts in the orchard, designed and managed to maximize seed production

**Strategy 1.3:** Restore populations in suitable habitat to sustain ecological function.

**Rationale:** Many areas urgently need restoration to re-establish unique ecological functions provided by five-needle pine ecosystems. Restoration may include planting, creating openings to encourage nutcracker caching, thinning competing species to promote five-needle pine, fuel reduction, or other actions. When resources are limited, they should be directed to priority areas. High priority areas may contain: high infection rate, high mortality, little or no regeneration, good accessibility, mature healthy tree basal area below or near 2 $m^2$/ha, declining mature tree canopy condition, limited plus tree proximity, poor connectivity (low likelihood of rescue from adjacent populations), and future habitat suitability under climate change, including moisture availability and drought potential. Monitoring is needed to assess and adapt procedures for success. Planting material should be seedlings or grafted cuttings from tested (elite) resistant trees; where those are not available or sufficient to meet demand, plus trees; where those are not available or sufficient to meet demand, the best available material. In areas with moderate to high rust hazard, only plus or elite material should be planted.

Collaboration is essential to meet population objectives across affected areas administered by different agencies. Both formal and informal mechanisms to support collaboration on recovery are in place in Alberta, including memoranda of understanding, data sharing agreements, and knowledge transfer. Supporting and strengthening these partnerships, building on existing partnerships, and including new partners will enhance access to habitat, aid in implementation scope and effectiveness, and build support for recovery.

**Desired outcome:** Restore a cumulative total of 100 ha by 2020, 1000 ha by 2025, with a target average of 100 ha per year subsequently, subject to seed availability and to be reassessed by 2050.

**Progress measures:**

1. Establishment of area priorities for restoration actions
2. Area restored
3. Number of seedlings planted

**Recovery actions:**

1. Monitor health and regeneration transects every 5 years
2. Prioritize areas for:
    a. planting
    b. daylighting/thinning
    c. fuel abatement
3. Build relationships among agencies and with landowners
4. Monitor periodically to gauge success of methods and durability of rust resistance

**Strategy 2:** Manage fuels and fire responses to restore fire regimes in five-needle pine habitat to within the historical range of variability.

**Rationale:** Decades of fire suppression have increased fuel loads, leading to higher chance of ignition and spread of fires. Summer droughts in five-needle pine habitat have become more intense and lasting as a result of climate change, which has increased the frequency and severity of fires, shifting the historical mixed fire regime to favour stand-replacing fires. Mountain pine beetle-caused mortality in northern stands has also increased fuel loads relative to historical norms, as mountain pine beetle recently expanded its range with climate warming. Severe fires severely hamper post-fire regeneration, kill mature cone-bearing trees, and can kill valuable plus trees. Restoration of historical fire regimes through a combination of modified response and targeted prescriptions should be supplemented with fuel management to better protect plus trees, conserve cone-producing stands, and enhance regeneration opportunities.

**Desired outcome:** Fire frequency and severity in whitebark and limber pine habitat is within historical range of variability.

**Progress measures:**

1. By 2050, fire severity and frequency in 40% of five-needle pine stands approach the range of historical variability.
2. By 2100, fire severity and frequency in 80% of five-needle pine stands approach the range of historical variability.

**Recovery actions:**

1. Collect baseline fuels and fire history data in five-needle pine stands to characterize historical fire regimes across the range of ecosystem types and relate those data, using a 2015 baseline, to regeneration.
2. Protect plus trees from fire where possible through collaboration with Wildfire Management Branch.
3. Develop or refine best practices for fire management in northern five-needle pine ecosystems.
4. Work with agency partners on communication, information sharing and methodology to increase acceptance of fire and to support program implementation.

**Strategy 3:** Address priority knowledge gaps.

**Rationale:** An expert workshop identified several key knowledge gaps related to recovery of whitebark and limber pine in Canada. Filling in these gaps is not a reason to delay or halt existing efforts, and recovery may still be successful if they remain unanswered, but addressing these topics may help direct limited resources where they may be most effective. Communication of research needs to those who can fill the needs and engage partners to pursue research questions is also needed. These topics would likely be addressed by external agencies and not directly by the recovery team. Other information gaps would be considered on a case-by-case basis.

Key knowledge gaps identified:

1. Status and trends of Clark's nutcracker in western Canada, including data on nutcracker population size, distribution and characteristics needed to sustain whitebark and limber pine metapopulations in Canada
2. Post-fire regeneration studies, particularly in northern stands
3. Identifying whether patterns exist among surficial parent material, rust resistance and adaptive traits in Alberta limber and whitebark pine (sensu Mahalovich *et al.* 2016); existing (US-based) analyses cannot be simply extended as Canada does not have the same geophysical data attributes, coverage and scale
4. Genetics of pine resistance to mountain pine beetle attack — this approach is not considered operationally feasible at this time but there is interest from a research perspective (contact Michael Murray (Michael.Murray@gov.bc.ca) with location and data of potentially mountain pine beetle-resistant trees)

5. Track limber and whitebark pine research recovery actions through a centralized system; possibly through Crown Managers Partnership High-Five Working Group or Whitebark Pine Ecosystem Foundation

   **Desired outcome:** Major knowledge gaps are filled by targeted studies and used to adapt recovery targets or measures where needed.

   **Progress measures:**

   1. By the next recovery plan revision, projects to address these topics are complete
   2. The next recovery plan revision and best practices guidance adopts this new knowledge

   **Recovery actions:**

   1. Share new research opportunities, funding sources and study findings
   2. Continue to connect and communicate with researchers to encourage pertinent research

# 8.0 Implementation Plan

## 8.1 Recovery Priorities

- Identify, protect and test plus trees.
- Collect seed from plus trees, then grow and plant seedlings.
- Monitor planted seedlings for health and performance
- Implement standardized operational guidelines and best practices for land use and development in whitebark and limber pine habitat designed to avoid, minimize then mitigate impacts, especially on plus trees and high-value stands.
- Collect data on fire history and risk in high-value stands to better understand appropriate use of fire as a tool to aid recovery.
- Monitor stand dynamics and health to support area prioritization and identify trends.
- Address identified key knowledge gaps with new studies.

## 8.2 Implementation Risks, Potential Barriers and Opportunities

A primary challenge is public and agency awareness of the endangered status and need for recovery. Both limber and whitebark pine currently appear abundant, but on closer inspection may actually be highly infected and lack regeneration. Targeted messaging to different user groups highlighting the pines' unique value and the urgency and benefits of recovery should increase support for recovery work.

Careful planning of land-use activities will minimize direct and ancillary impacts, which are typically limited. Most whitebark and limber pine in Alberta occur in protected areas, but data has shown that passive protection is not sufficient to mitigate the most significant threats to these species or halt their decline. Agencies administering those areas have mandates to conserve and recover endangered species and their habitat. For all land bases, operational guidelines and best practices for land use are regularly revised and updated (Appendix 2).

The main barriers to implementation are the cost of accessing and managing remote areas, and the long time frame needed for success. Coordinating work among many agencies is a challenge, as funding cycles align poorly with biological windows and multi-year implementation actions.

However, this is an incentive to share resources and make recovery efforts more efficient through sharing knowledge, data, materials and resources. The established (and growing) network of partners and information sharing, nationally and internationally, is a great opportunity and strength for these species. A model of success for whitebark pine recovery is the Greater Yellowstone Ecosystem Coordinating Committee — Whitebark Pine Subcommittee, which has been working since 2006 within the Greater Yellowstone Area to coordinate protection, recovery planning, implementation and tracking, and support research and knowledge sharing across jurisdictions.

## 8.3 Approaches and Responsibility for Implementing Major Activities or Strategies

Table 3 outlines the priorities, partners and timing for implementation of actions. “Urgent” activities (level 1) are the highest priority for immediate species conservation and should be initiated as soon as possible. “Necessary” activities (level 2) are medium priority actions affecting long-term species conservation. “Beneficial” activities (level 3) are lower priority and will be undertaken on an intermittent or opportunistic basis as resources allow. AAF and AEP represent agency actions or actions by members of the recovery implementation team. The *Multi-species Action Plan for Banff National Park of Canada*, the *Multi-species Action Plan for Jasper National Park of Canada*, and the *Multi-species Action Plan for Waterton Lakes National Park of Canada and Bar U Ranch National Historic Site of Canada* identify the recovery measures that will be implemented and reported on in these protected heritage places. The Parks Canada Agency works collaboratively with the province of Alberta and is a lead agency for many shared priority recovery measures.

### Table 3. Whitebark and limber pine recovery action implementation table.

| Strategy | Action | Priority | Lead Agencies[1] | Schedule for Completion |
|---|---|---|---|---|
| 1.1. Identify, protect and test plus trees | Select plus trees in highly infected stands | 1 | AAF, PC | Ongoing |
| | Collect seeds | 1 | AAF, PC | Ongoing |
| | Screen plus trees using accepted methods | 1 | PC, AAF, AEP, CFS | Ongoing |
| | Protect plus trees | 1 | AAF, PC, AEP | Ongoing |
| | Develop, provide, and update best practices for operations in 5NP habitat | 1 | AAF, AEP | Available; update as needed |
| 1.2. Develop at least one seed orchard for each species sufficient to supply seed to meet restoration needs | Clarify agency seed orchard roles and responsibilities | 2 | AAF, PC, NGOs | 2021 |
| | Assess seed and seed orchard needs | 2 | AAF, PC, ACAD | 2021 |
| | Secure and prepare suitable seed orchard sites | 1 | AAF, PC, NGO | 2022 |
| | Collect and graft scions from plus trees onto rootstock | 2 | AAF, PC | Ongoing |
| | Establish grafts in the seed orchard | 2 | AAF, PC, NGOs | 2025 |
| 1.3. Restore populations in suitable habitat to sustain ecological function | Monitor health and regeneration transects every 5 years | 1 | AAF, PC, AEP | Ongoing every 5 years e.g., 2024, 2029, etc. |
| | Prioritize areas for restoration actions | 1 | AAF, PC, (AEP) NGOs | Ongoing |
| | Build relationships among agencies and with landowners | 3 | AAF, PC, NGOs, (AEP) | Ongoing |
| | Monitor restoration outcomes | 2 | AAF, PC, AEP | Ongoing |
| 2. Manage fuels and fire responses to restore fire regimes in five-needle pine habitat to within the historical range of variability | Protect plus trees from fire | 1 | AAF, PC, AEP | Ongoing |
| | Work with agency partners to increase acceptance of fire in 5NP ecosystems | 2 | AAF, PC, AEP, NGOs | Ongoing |

| Strategy | Action | Priority | Lead Agencies[1] | Schedule for Completion |
|---|---|---|---|---|
| 3. Address priority knowledge gaps | Share new research opportunities, funding sources, and study findings | 2 | AAF, PC, AEP, CFS, WPEF, ACAD | Ongoing |

Lead agencies: AEP — Alberta Environment and Parks, AAF — Alberta Agriculture and Forestry; PC — Parks Canada; CFS — Canadian Forest Service; ACAD — academia; NGO — non-governmental organizations; WPEF — Whitebark Pine Ecosystem Foundation.

## 8.4 Progress Reporting and Work Plan

This plan will be reviewed every five years — a short window in the necessary recovery horizon of these slow-growing trees. A seed collected now produces a seedling that can be planted in three to five years, which will begin reproducing (if it is not killed by blister rust) in 50 to 80 years, reaching a consistent reproductive output after age 80 to 100. The necessary steps of waiting for mast years to collect cones, and selecting and screening plus trees for disease resistance, add up to approximately 10 years. Alberta Environment and Parks and Alberta Agriculture and Forestry review activities annually to monitor the implementation of the plan and determine the effectiveness of recovery actions. A summary is submitted annually to the government branch responsible for provincial recovery plans. Recovery plans are living documents and actions or targets can be amended following reviews, as new information becomes available, as conditions change, or as circumstances warrant. After ten years, management strategies and actions will be reviewed and may be revised as appropriate.

# 9.0 Socio-economic Scan

This section is intended to provide an overview of current and past social and economic considerations in Alberta that might interact with the conservation of whitebark and limber pine populations and the implementation of the actions in this plan. The scan identifies issues that may have costs and benefits to stakeholders that will need to be considered during the implementation of the recovery plan. The potential impacts are scored as either positive or negative (Table 4).

Recovery efforts in Alberta should have minimal economic impacts on industries working in whitebark or limber pine habitat. The largest overlaps are with forestry and ranching, although the effect is small because of the small areas of occupied and suitable habitat affected by these land uses in Alberta. Removing lodgepole pine or other competing trees to protect whitebark pine trees from competition-induced mortality could affect the timber resources in localized areas, but can be planned to retain a fully stocked stand of merchantable crop species. Lodgepole pine removal to reduce mountain pine beetle hazard in whitebark or limber pine stands may have a short-term detrimental effect for timber volume but a medium- to long-term benefit by reducing losses to mountain pine beetle. Stand and transect monitoring may provide an early warning for potential new or spreading diseases or pests that can spur proactive management of timber resources. Deploying verbenone, alone or in combination with green-leaf volatiles, to protect high-value trees and stands has only a limited effective radius and therefore a localized impact; and is only effective for up to moderate levels of infestation. These treatments significantly reduce targeted tree mortality under these conditions (Gillette *et al.* 2014). Protection of sites containing high-value trees or stands may increase planning and operational costs for industry in localized spots. Road and cutblock boundary re-alignment, moving infrastructure footprints, adjusting right-of-way clearance, ski facility infrastructure, ski run creation and maintenance, and hiking or biking trail alignment all may be affected to a small degree. Other activities such as inventory, monitoring, research, collecting cones, disease resistance screening, seedling planting or tree breeding would have minimal effect on other interests or other species.

Although limber pine often occurs on lands with cattle grazing, recovery actions may only incur minor localized impacts on landowners or leaseholders if they choose to exclude cattle to deter trampling of regeneration. Limber pine trees provide protection for cattle from wind. Many Alberta landowners and leaseholders have granted access for limber pine projects, and expressed support for recovery in general, as well as for monitoring, plus tree identification and cone collection work.

Impacts on energy production are negligible, limited to small project-specific costs for footprint realignment. Recreational user groups support maintaining whitebark and limber pines on the landscape as key biodiversity components and aesthetically appealing trees. The Whitebark Pine

Ecosystem Foundation has a voluntary “whitebark-friendly” ski hill certification program, for which several Alberta ski hills are in the process of qualifying. Some follow-up monitoring costs may be incurred to assess the degree and duration of impact (if any). Participating industries may benefit from third-party sustainability certification, and client support for voluntary environmental initiatives.

**Table 44. Anticipated social and economic impacts of implementation of the whitebark and limber pine recovery plan.**

| Strategy | Action | Socioeconomic Impacts (-) is a cost, (+) is a benefit |
|---|---|---|
| Identify, protect, and test plus trees | Monitor stand health and dynamics every five years (Tomback *et al.* 2005) | (+) consistent science-based method to meet recovery objectives<br>(+) target limited resources to top priority areas<br>(-) cost of activity |
| | Select plus trees in highly infected stands | (+) only means of procuring seed at this time<br>(-) cost of collection |
| | Collect seeds | (+) only means of procuring seed at this time<br>(-) cost of collection |
| | Screen plus trees using accepted methods | (+) reduce impacts to high-value trees<br>(-) cost of adjusting planning in industry overlap areas |
| | Based on mountain pine beetle and fire hazard and development applications, protect plus trees | (+) reduce impacts to high-value trees<br>(+) where other priorities allow, support interagency collaboration<br>(-) small cost of adjusting planning in industry overlap areas |
| | Develop and provide best practices for operations in 5NP habitat | (+) current, consistent, user-friendly guidance freely available |

| Strategy | Action | Socioeconomic Impacts (-) is a cost, (+) is a benefit |
|---|---|---|
| **Develop at least one seed orchard for each species sufficient to supply seed to meet restoration needs.** | **Clarify agency roles and responsibilities** | **(+) consistent clear guidance and planning to meet seed needs**<br>**(+) identify opportunities for resource sharing (genotypes, sites, expertise, manpower)** |
| **Develop at least one seed orchard for each species sufficient to supply seed to meet restoration needs.** Restore habitat to sustain ecological function | Assess seed and seed orchard needs | (+) consistent clear guidance and planning to meet seed needs<br>(+) identify opportunities for resource sharing (genotypes, sites, expertise, manpower) |
| | Secure and prepare suitable sites, ideally multiple sites per species and seed zone (cleared, fenced, disposition if required, etc.) | (+) certainty to protect investment in seed orchard<br>(+) build collaborative relationships across jurisdictions and agencies<br>(-) cost of site and/or activity |
| | Collect and graft scions from plus trees onto rootstock | (+) duplicate rare genotypes for protection and propagation<br>(+) scion collection can be done at same time as cone collection<br>(-) cost of collection, grafting, rootstock production |
| | Establish grafts in the orchard, designed and managed to maximize seed production | (+) the most reliable and quickest way to build a restoration seed source<br>(+) build collaborative relationships across jurisdictions and agencies<br>(-) cost of activity |
| | Prioritize areas for recovery actions | (+) data to prioritize actions for rare rust-resistant genotypes<br>(+) consistent clear planning to meet recovery objectives<br>(-) cost of activity |
| Restore habitat to sustain ecological function Manage fuels and fire responses to restore fire regimes in 5NP habitat to within the historical range of variability. | Build relationships among agencies and with landowners | (+) identify opportunities for resource sharing (genotypes, sites, expertise, manpower)<br>(+) build collaborative relationships across jurisdictions and agencies |
| | Monitor key attributes to assess effectiveness and adjust methods based on those results | (+) consistent science-based approach to determine best methods to meet recovery objectives<br>(-) cost of activity |
| | Collect baseline fuel and fire history data in 5NP stands, starting in 2015, to characterize historical fire regimes across the range of ecosystem types and relate those data to regeneration | (-) cost of data collection (minimized, done at same time as 5-year monitoring)<br>(+) potential improvement to recovery outcomes with new data |

| Strategy | Action | Socioeconomic Impacts (-) is a cost, (+) is a benefit |
|---|---|---|
| Manage fuels and fire responses to restore fire regimes in 5NP habitat to within the historical range of variability.<br>Address identified priority knowledge gaps | Protect plus trees from fire where possible through collaboration with Wildfire Management Branch | (+) reduce impacts to high-value stands and trees<br>(-) if other fire protection priorities exist at a 5NP site, there may be an incremental cost to protect 5NP |
| | Develop or refine best practices for fire management in northern 5NP ecosystems | (+) current, consistent, user-friendly guidance freely available<br>(+) template available from Crown of the Continent BMPs for 5NP and fire |
| | Work with agency partners on extension and methodology to increase acceptance of fire and to support program implementation | (+) opportunities for inter-agency collaboration<br>(+) potential to save fire suppression costs with modified response<br>(+) opportunity to gain operational expertise in modified response |
| | Share new research opportunities, funding sources, and study findings | (+) opportunities for inter-agency collaboration<br>(+) fill knowledge gaps in Canada/Alberta to optimize BMPs |

Ecosystem services such as modifying mountain streamflow timing and peak flow levels, treeline initiation and slope stability support are valuable non-monetized benefits provided by these trees that influence watershed function, habitat of temperature-sensitive fish species, and water availability in areas such as southern Alberta where water licences are fully allocated. Ensuring a sufficient density of cone-producing trees in a stand is necessary to sustain these tree species and their dispersal agent Clark's nutcracker, which is an attractive species to birdwatchers and mountain visitors who provide revenues for parks and mountain communities.

Wildfire control activities and modification of prescribed burn prescriptions to protect high-value whitebark or limber pine trees and stands could reduce some stand-level ecological benefits that occur in the wake of fire. Impacts and benefits would vary with the severity and size of fire and the desired outcome.

Little is known about the traditional use of whitebark or limber pine by Indigenous peoples in Alberta; however, whitebark pine was, and in many areas still is, used in other areas of its range for food (Turner *et al.* 1980; Lee 2003; Keane *et al.* 2012). Elders of the Blackfoot Confederacy describe many uses of whitebark pine sap and needles (Augare-Estey 2011), and it is likely that limber pine was used in similar ways. While some elders voiced concern over human intervention in whitebark pine restoration, there was some consensus that if done properly it would be beneficial (Augare-Estey 2011). The BC Thompson and Ts'ilhqot'in people collected whitebark pine cones and extracted the seeds to eat fresh or preserved them for winter use by roasting, then crushing them and mixing them with dried berries, or by pounding the roasted seeds into flour (Turner 1997). The inner bark of whitebark pine was used for food or medicine for digestive problems (Turner *et al.* 1980; Kuhmlein and Turner 1991), and the fibrous roots were sometimes used for weaving into canoes and watertight containers, and for sewing pieces of bark together (Parish *et al.* 1999). The Ktunaxa in the Kootenay region may have eaten and traded limber pine seeds, and propagated them along traditional trade routes (R. Moody, pers. comm). Prehistoric grinding stones found in Nevada were likely used on limber pine seeds (Lanner 1996). The Apache, Chiricahua and Mescalero were reported to roast and hull the seeds or sometimes to grind and eat the seeds, including the shell (Castetter and Opler 1936).The Navajo used the tree as a ceremonial emetic and as a medicine for cough and fever, also smoking the plant (Vestal 1952) and burning the seeds (Kershaw *et al.* 1998) for good luck.

# 10.0 Effects on Other Species at Risk

Whitebark pine and limber pine both co-occur with several species at risk in Alberta. Ensuring the best outcomes for sympatric species at risk requires careful consideration and application of current science, and collaborating with stakeholders. Monitoring is important to determine thresholds or differences from treatment levels, differences among habitat types, or applicability of results from other jurisdictions. Effects of these species and their recovery are either positive or neutral, described below by species.

Grizzly bears (Canada: *Special Concern*, Alberta: *Threatened*) use the rich seeds of these species for food in Alberta and BC. Unlike in Yellowstone, where a strong preference of grizzly bears for whitebark pine seed was documented and seed abundance was linked to the degree of human/wildlife interactions and reproductive success, in Alberta their use seems opportunistic, depending on cone crops and availability of other food sources. This may also reflect ecological differences, where extensive pure whitebark pine stands occur in Yellowstone but are very uncommon in Alberta. Use of limber pine was also observed in US studies of bears, but of the limited studies in Canada, limber pine seed appears to be consumed primarily from squirrel middens, rather than directly from trees (Hamer 2016).

Several southern mountain caribou subpopulations co-occur with whitebark pine in Alberta; federally, two are *Threatened* and one *Endangered*, and all are *Threatened* provincially. However, whitebark pine forests are not characteristic of caribou preferred summer habitat (Environment Canada 2014). Some use of potential whitebark pine habitat during calving is documented in BC (Bergerud *et al.* 1984; Seip and Cichowski 1996). Fire would reduce lichen forage for caribou, and more severe fire may reduce caribou thermal cover value, but may also kill whitebark pine seedlings and trees. From a population perspective, the spatial impact of fire in whitebark pine stands, relative to the occupancy and use of caribou herds, is negligible. Within their ranges, caribou should be able to find suitable unburnt areas to occupy even if some areas are burnt. Delineating potential conflict zones can mitigate negative effects related to fire management and whitebark pine.

Both whitebark and limber pine occur within the range of freshwater salmonids at risk in some areas: westslope cutthroat trout (*Threatened* federally and provincially), Athabasca rainbow trout (federally *Endangered*, *Threatened* in Alberta), bull trout (federally divided into two designatable units, one of which is *Threatened*, the other is *Special Concern*; *Threatened* in Alberta), and Rocky Mountain sculpin (Eastslope population *Threatened* federally and provincially). Habitat loss and degradation are primary drivers of the declines of these species. Should whitebark and limber pine continue to decline, headwater stream hydrology would be affected by having earlier snowmelt pulses and higher peak flows, with potential lethal heating and low water levels in streams later in the summer.

Little brown myotis and northern myotis, bat species that are both *Endangered* federally as a result of white-nose syndrome, have potential overlap with whitebark pine, but are not confirmed to actually roost in or use these habitats. Both species have distributions in Canada beyond Alberta. No conflicts are identified.

Ferruginous hawk is *Threatened* federally and in Alberta. Its breeding habitat overlaps limber pine in the Rocky Mountain foothills, but its primary habitat is the grasslands, extending into the prairies and the US. No conflicts are identified.

Porsild's bryum is a moss species *Threatened* federally and identified as *Endangered* in Alberta, which has numerous known occurrences in whitebark pine habitat in the Rocky Mountains. It grows directly on rock substrate and is threatened by restricted known habitat, population isolation and risk of destabilization of suitable substrates. The species is recorded at over 1200 colonies at 15 sites in Alberta, several other disjunct sites in northern Canada and the US, and has a Holarctic distribution. No conflicts are identified.

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# 12.0 Appendix 1. Threat assessments for limber and whitebark pines.

## A.1 Threat Assessment for Whitebark Pine

| | |
|---|---|
| **Species or Ecosystem Scientific Name** | Whitebark Pine, Alberta |
| **Date:** | 8/24/2021 |
| **Assessor(s):** | Robin Gutsell, Jodie Krakowski |
| **References:** | Based on national Threat Assessment for whitebark pine completed in 2013, modified 2020-2021; also informed by Threat Assessment for whitebark pine completed by national five-needle pine Open Standards recovery group, based on slightly different Miradi methodology |

**Overall Threat Impact Calculation Help:**

| | | Level 1 Threat Impact Counts | |
|---|---|---|---|
| **Threat Impact** | | **high range** | **low range** |
| A | Very High | 1 | 1 |
| B | High | 0 | 0 |
| C | Medium | 3 | 2 |
| D | Low | 0 | 1 |
| **Calculated Overall Threat Impact:** | | Very High | Very High |

| | |
|---|---|
| **Assigned Overall Threat Impact:** | **A = Very High** |
| **Impact Adjustment Reasons:** | Main threat from white pine blister rust is sufficient to reduce the population severely over the next three generations/100 years, with other threats adding to the main threat. The impact of white pine blister rust over ten years is expected to be less than for 100 years. |
| **Overall Threat Comments:** | Three generations exceeds 100 years |

| Threat | | Impact (calculated) | | Scope (next 10 Yrs) | Severity (10 Yrs or 3 Gen.) | Timing | Comments |
|---|---|---|---|---|---|---|---|
| 1 | Residential & commercial development | | Negligible | Negligible (<1%) | Moderate (11-30%) | High (Continuing) | |
| 1.1 | Housing & urban areas | | | | | | |
| 1.2 | Commercial & industrial areas | | | | | | |
| 1.3 | Tourism & recreation areas | | Negligible | Negligible (<1%) | Moderate (11-30%) | High (Continuing) | Ski hills, heli-skiing and cat skiing glading, potential developments in the future. Backcountry cabins are rare in Alberta. |
| 2 | Agriculture & aquaculture | | | | | | |
| 2.1 | Annual & perennial non-timber crops | | | | | | |
| 2.2 | Wood & pulp plantations | | | | | | |
| 2.3 | Livestock farming & ranching | | | | | | Ranching doesn't occur within whitebark range |
| 2.4 | Marine & freshwater aquaculture | | | | | | |
| 3 | Energy production & mining | CD | Medium - Low | Restricted - Small (1-30%) | Extreme (71-100%) | High (Continuing) | |
| 3.1 | Oil & gas drilling | | Negligible | Negligible (<1%) | Extreme (71-100%) | High (Continuing) | Very small footprint |
| 3.2 | Mining & quarrying | CD | Medium - Low | Restricted - Small (1-30%) | Extreme (71-100%) | High (Continuing) | Mostly potential coal mines. Recent uncertainty about whether areas will be opening up for coal mining. |

| Threat | | Impact (calculated) | | Scope (next 10 Yrs) | Severity (10 Yrs or 3 Gen.) | Timing | Comments |
|---|---|---|---|---|---|---|---|
| 3.3 | Renewable energy | | | | | | No proposed activity in WB habitat |
| 4 | Transportation & service corridors | | Negligible | Negligible (<1%) | Extreme (71-100%) | High (Continuing) | |
| 4.1 | Roads & railroads | | Negligible | Negligible (<1%) | Extreme (71-100%) | High (Continuing) | Roads are relevant to commercial and industrial development as well as public transportation. Depending on the size of development the road size and impacts may vary. |
| 4.2 | Utility & service lines | | Negligible | Negligible (<1%) | Extreme (71-100%) | High (Continuing) | Clearing for power lines |
| 4.3 | Shipping lanes | | | | | | |
| 4.4 | Flight paths | | | | | | |
| 5 | Biological resource use | | Negligible | Negligible (<1%) | Extreme (71-100%) | High (Continuing) | |
| 5.1 | Hunting & collecting terrestrial animals | | | | | | |
| 5.2 | Gathering terrestrial plants | | Not a Threat | Negligible (<1%) | Neutral or Potential Benefit | Insignificant /Negligible (Past or no direct effect) | Traditional use and gathering occurs to small extent |
| 5.3 | Logging & wood harvesting | | Negligible | Negligible (<1%) | Extreme (71-100%) | High (Continuing) | In Alberta, little incidental harvest (compared to BC). Active attempts to reduce harvest and discouragement within policy but no regulatory mechanisms, impacts of replacement of whitebark stands with monoculture of other tree species. |
| 5.4 | Fishing & harvesting aquatic resources | | | | | | |
| 6 | Human intrusions & disturbance | | Negligible | Negligible (<1%) | Slight (1-10%) | High (Continuing) | |

| **Threat** | | **Impact (calculated)** | | **Scope (next 10 Yrs)** | **Severity (10 Yrs or 3 Gen.)** | **Timing** | **Comments** |
|---|---|---|---|---|---|---|---|
| 6.1 | Recreational activities | | Negligible | Negligible (<1%) | Slight (1-10%) | High (Continuing) | ATVs, backcountry lodges, backcountry visitors on trails (ground compression, climbing on trees, trail clearing), increased access from road networks, burning for campfires, bike trail construction. |
| 6.2 | War, civil unrest & military exercises | | | | | | |
| 6.3 | Work & other activities | | | | | | |
| 7 | Natural system modifications | C | Medium | Restricted (11-30%) | Serious (31-70%) | High (Continuing) | |
| 7.1 | Fire & fire suppression | C | Medium | Restricted (11-30%) | Serious (31-70%) | High (Continuing) | Severe fires outside the range of historical variability cause mortality, and fire suppression causes successional change and reduces regeneration sites. Mixed severity burns are best to retain regeneration sites as well as mature trees. Climate change can affect fire severity and frequency. Fire suppression may compound the threat of mountain pine beetle. |
| 7.2 | Dams & water management/use | | | | | | |
| 7.3 | Other ecosystem modifications | | | | | | |
| 8 | Invasive & other problematic species & genes | A | Very High | Pervasive (71-100%) | Extreme (71-100%) | High (Continuing) | |
| 8.1 | Invasive non-native/alien species | A | Very High | Pervasive (71-100%) | Extreme (71-100%) | High (Continuing) | White Pine Blister Rust; *Ribes* are alternate hosts and potentially paintbrush.  Natural resistance levels are much lower than 30%. |

| Threat | | Impact (calculated) | | Scope (next 10 Yrs) | Severity (10 Yrs or 3 Gen.) | Timing | Comments |
|---|---|---|---|---|---|---|---|
| 8.2 | Problematic native species | C | Medium | Restricted (11-30%) | Extreme - Serious (31-100%) | High (Continuing) | Mountain pine beetle; unknowns about future impacts of pine beetle as outbreak has scaled down recently. More impact on mature trees than on young trees; cannot assume that all young trees will become mature; pine beetle may be taking out rust-resistant trees (interaction between blister rust and pine beetle). |
| 8.3 | Introduced genetic material | | | | | | |
| 9 | Pollution | | | | | | |
| 9.1 | Household sewage & urban waste water | | | | | | |
| 9.2 | Industrial & military effluents | | | | | | |
| 9.3 | Agricultural & forestry effluents | | | | | | |
| 9.4 | Garbage & solid waste | | | | | | |
| 9.5 | Air-borne pollutants | | | | | | |
| 9.6 | Excess energy | | | | | | |
| 10 | Geological events | | Negligible | Negligible (<1%) | Extreme (71-100%) | High (Continuing) | |
| 10.1 | Volcanoes | | | | | | |
| 10.2 | Earthquakes /tsunamis | | | | | | |
| 10.3 | Avalanches /landslides | | Negligible | Negligible (<1%) | Extreme (71-100%) | High (Continuing) | Thinning of population may impact severity of avalanches and wind damage, climate change has potential to increase severity and timing of avalanches |
| 11 | Climate change & severe weather | C | Medium | Restricted (11-30%) | Serious (31-70%) | High (Continuing) | |

| Threat | | Impact (calculated) | | Scope (next 10 Yrs) | Severity (10 Yrs or 3 Gen.) | Timing | Comments |
|---|---|---|---|---|---|---|---|
| 11.1 | Habitat shifting & alteration | C | Medium | Restricted (11-30%) | Serious (31-70%) | High (Continuing) | At lower elevations encroachment by other species; distribution shifts observed in JNP.  Expect changes in fire regimes, mountain pine beetle, moisture and, temperature regimes, mature trees can withstand disturbance and stress better than young trees, expect a more extreme disturbance regime, great uncertainty; the response to climate change is likely variable. |
| 11.2 | Droughts | D | Low | Small (1-10%) | Serious - Moderate (11-70%) | High (Continuing) | Drought affecting regeneration in eastern part of AB range (or where growth is moisture limited). Potential to increase in severity in the future. |
| 11.3 | Temperature extremes | C D | Medium - Low | Pervasive (71-100%) | Moderate - Slight (1-30%) | Moderate (Possibly in the short term, < 10 yrs/3 gen) | Failure in plantings during heat waves (possibly also in natural regeneration). Potential effects on seed viability, direct death, temperature extremes exacerbate other stressors, uncertainty about response of ecosystem to increased temperatures - there could be positive effects on growth. Could also cause increased competition from other species. |
| 11.4 | Storms & flooding | | | | | | Species is not greatly affected by storms |

## A.2 Threat Assessment for Limber Pine

| | |
|---|---|
| **Species or Ecosystem Scientific Name** | Limber Pine, Alberta |
| **Date:** | 8/24/2021 |
| **Assessor(s):** | Robin Gutsell, Jodie Krakowski |
| **References:** | Based on national Threat Assessment for whitebark pine completed in 2013, modified 2020-2021; also informed by Threat Assessment for whitebark pine completed by national five-needle pine Open Standards recovery group, based on slightly different Miradi methodology |

**Overall Threat Impact Calculation Help:**

| | | **Level 1 Threat Impact Counts** | |
|---|---|---|---|
| **Threat Impact** | | **high range** | **low range** |
| A | Very High | 1 | 1 |
| B | High | 0 | 0 |
| C | Medium | 3 | 2 |
| D | Low | 1 | 2 |
| **Calculated Overall Threat Impact:** | | Very High | Very High |

| | |
|---|---|
| **Assigned Overall Threat Impact:** | **A = Very High** |
| **Impact Adjustment Reasons:** | Main threat from white pine blister rust is sufficient to reduce the population severely over the next three generations/100 years, with other threats adding to the main threat. The impact of white pine blister rust over ten years is expected to be less than for 100 years. |
| **Overall Threat Comments:** | Three generations exceeds 100 years |

| Threat | | Impact (calculated) | | Scope (next 10 Yrs) | Severity (10 Yrs or 3 Gen.) | Timing | Comments |
|---|---|---|---|---|---|---|---|
| 1 | Residential & commercial development | | Negligible | Negligible (<1%) | Moderate (11-30%) | High (Continuing) | |
| 1.1 | Housing & urban areas | | | | | | |
| 1.2 | Commercial & industrial areas | | | | | | |
| 1.3 | Tourism & recreation areas | | Negligible | Negligible (<1%) | Negligible (<1%) | High (Continuing) | Ski hills in AB have whitebark, but not limber pine. |
| 2 | Agriculture & aquaculture | D | Low | Small (1-10%) | Moderate – Slight (1-30%) | High (Continuing) | |
| 2.1 | Annual & perennial non-timber crops | | | | | | |
| 2.2 | Wood & pulp plantations | | | | | | |
| 2.3 | Livestock farming & ranching | D | Low | Small (1-10%) | Moderate – Slight (1-30%) | High (Continuing) | This impact applies more to trampling of regeneration than to mature trees - cattle can destroy up to 100% of regeneration that they have access to. Cattle also break cone-bearing branches within their reach. |
| 2.4 | Marine & freshwater aquaculture | | | | | | |
| 3 | Energy production & mining | C | Medium | Restricted (11-30%) | Extreme (71-100%) | High (Continuing) | |
| 3.1 | Oil & gas drilling | | Negligible | Negligible (<1%) | Extreme (71-100%) | Low (Possibly in the long term, >10 yrs/3 gen)) | Nothing new likely but possible over longer term. |
| 3.2 | Mining & quarrying | C | Medium | Restricted (11-30%) | Extreme (71-100%) | High (Continuing) | Mostly potential coal mines.  Recent uncertainty about whether areas will be opening up for coal mining. |
| 3.3 | Renewable energy | | Negligible | Negligible (<1%) | Serious (31-70%) | High (Continuing) | Wind farm potential in the future in limber range. |

| Threat | | Impact (calculated) | Scope (next 10 Yrs) | Severity (10 Yrs or 3 Gen.) | Timing | Comments |
|---|---|---|---|---|---|---|
| 4 | Transportation & service corridors | Negligible | Negligible (<1%) | Extreme (71-100%) | High (Continuing) | |
| 4.1 | Roads & railroads | Negligible | Negligible (<1%) | Extreme (71-100%) | High (Continuing) | Roads are relevant to commercial and industrial development as well as public transportation. Depending on the size of development the road size and impacts may vary. |
| 4.2 | Utility & service lines | Negligible | Negligible (<1%) | Extreme (71-100%) | High (Continuing) | Clearing for power lines |
| 4.3 | Shipping lanes | | | | | |
| 4.4 | Flight paths | | | | | |
| 5 | Biological resource use | Negligible | Negligible (<1%) | Extreme (71-100%) | High (Continuing) | |
| 5.1 | Hunting & collecting terrestrial animals | | | | | |
| 5.2 | Gathering terrestrial plants | Not a Threat | Negligible (<1%) | Neutral or Potential Benefit | Insignificant /Negligible (Past or no direct effect) | Traditional use and gathering occurs to small extent |
| 5.3 | Logging & wood harvesting | Negligible | Negligible (<1%) | Extreme (71-100%) | High (Continuing) | In Alberta, little incidental harvest (compared to BC). Active attempts to reduce harvest and discouragement within policy but no regulatory mechanisms, impacts of replacement of whitebark stands with monoculture of other tree species. |
| 5.4 | Fishing & harvesting aquatic resources | | | | | |
| 6 | Human intrusions & disturbance | Negligible | Negligible (<1%) | Slight (1-10%) | High (Continuing) | |
| 6.1 | Recreational activities | Negligible | Negligible (<1%) | Slight (1-10%) | High (Continuing) | ATVs, backcountry lodges, backcountry visitors on trails (ground compression, climbing on trees, trail clearing), increased access from road networks, burning for campfires, bike trail construction. |

| Threat | | Impact (calculated) | | Scope (next 10 Yrs) | Severity (10 Yrs or 3 Gen.) | Timing | Comments |
|---|---|---|---|---|---|---|---|
| 6.2 | War, civil unrest & military exercises | | | | | | |
| 6.3 | Work & other activities | | | | | | |
| 7 | Natural system modifications | C | Medium | Restricted (11-30%) | Serious (31-70%) | High (Continuing) | |
| 7.1 | Fire & fire suppression | C | Medium | Restricted (11-30%) | Serious (31-70%) | High (Continuing) | Severe fires outside the range of historical variability cause mortality, and fire suppression causes successional change and reduces regeneration sites. Mixed severity burns are best to retain regeneration sites as well as mature trees. Climate change can affect fire severity and frequency. Fire suppression may compound the threat of mountain pine beetle. |
| 7.2 | Dams & water management/use | | | | | | |
| 7.3 | Other ecosystem modifications | | | | | | |
| 8 | Invasive & other problematic species & genes | A | Very High | Pervasive (71-100%) | Extreme (71-100%) | High (Continuing) | |
| 8.1 | Invasive non-native/alien species | A | Very High | Pervasive (71-100%) | Extreme (71-100%) | High (Continuing) | White Pine Blister Rust; *Ribes* are alternate hosts and potentially paintbrush. Natural resistance levels are much lower than 30%. |
| 8.2 | Problematic native species | D | Low | Small (1-10%) | Extreme - Serious (31-100%) | High (Continuing) | Mountain pine beetle; unknowns about future impacts of pine beetle as outbreak has scaled down recently. More impact on mature trees than on young trees; cannot assume that all young trees will become mature; pine beetle may be taking out rust-resistant trees (interaction between blister rust and pine beetle). |
| 8.3 | Introduced genetic material | | | | | | |
| 9 | Pollution | | | | | | |
| 9.1 | Household sewage & urban waste water | | | | | | |
| 9.2 | Industrial & military effluents | | | | | | |

| **Threat** | | **Impact (calculated)** | | **Scope (next 10 Yrs)** | **Severity (10 Yrs or 3 Gen.)** | **Timing** | **Comments** |
|---|---|---|---|---|---|---|---|
| 9.3 | Agricultural & forestry effluents | | | | | | |
| 9.4 | Garbage & solid waste | | | | | | |
| 9.5 | Air-borne pollutants | | | | | | |
| 9.6 | Excess energy | | | | | | |
| 10 | Geological events | | Negligible | Negligible (<1%) | Extreme (71-100%) | High (Continuing) | |
| 10.1 | Volcanoes | | | | | | |
| 10.2 | Earthquakes /tsunamis | | | | | | |
| 10.3 | Avalanches /landslides | | | | | | |
| 11 | Climate change & severe weather | CD | Medium - Low | Restricted (11-30%) | Serious - Moderate (11-70%) | High (Continuing) | |
| 11.1 | Habitat shifting & alteration | D | Low | Restricted (11-30%) | Moderate (11-30%) | High (Continuing) | Expect changes in fire regimes, mountain pine beetle, moisture regimes, temperature regimes, mature trees can withstand disturbance and stress more than young trees, expect a more extreme disturbance regime, great uncertainty; the response to climate change is likely variable. |
| 11.2 | Droughts | CD | Medium - Low | Restricted (11-30%) | Serious - Moderate (11-70%) | High (Continuing) | Drought may affect regeneration, especially in eastern part of Alberta range (or where growth is moisture limited). Potential to increase in severity in the future. |
| 11.3 | Temperature extremes | CD | Medium - Low | Pervasive (71-100%) | Moderate - Slight (1-30%) | Moderate (Possibly in the short term, < 10 yrs/3 gen) | Potential effects on seed viability and direct death, temperature extremes exacerbate other stressors, uncertainty about response of ecosystem to increased temperatures - there could be positive effects on growth. Could also cause increased competition from other species. |
| 11.4 | Storms & flooding | | | | | | Species is not greatly affected by storms |

# 13.0 Appendix 2. Resources for guidance and best practices.

Links to guidance on operating in whitebark and limber pine habitat, are available through the recovery team (goa.endangeredpine@gov.ab.ca). Resources currently available include:

- Master Schedule of Standards and Conditions. URL: https://open.alberta.ca/publications/master-schedule-of-standards-and-conditions
- Best Management Practices for Whitebark Pine (*Pinus albicaulis*) – available upon request from the recovery team (goa.endangeredpine@gov.ab.ca).
- Recovery Strategy for the Whitebark Pine (*Pinus albicaulis*) in Canada – draft strategy URL: https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html
- Promoting Whitebark Pine Recovery in British Columbia. URL: https://sernbc.ca/uploads/14/Promoting_Whitebark_Pine_Recovery_in_BC.pdf
- Multi-species Action Plan for Jasper National Park of Canada. URL: https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html
- Multi-species Action Plan for Waterton Lakes National Park of Canada and Bar U Ranch National Historic Site of Canada. URL: https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html
- Genetic Conservation Strategy for Whitebark Pine in British Columbia. URL: https://forestgeneticsbc.ca/wp-content/uploads/2020/07/Genetic-conservation-strategy-for-whitebark-pine-in-British-Columbia-March-2009.pdf
- Silvicultural Options for the Endangered Whitebark Pine. URL: https://forestgeneticsbc.ca/wp-content/uploads/2020/07/Forest-Health-Silvicultural-Options-for-the-Endangered-Whitebark-Pine-2013-1.pdf
- A range-wide restoration strategy for whitebark pine (*Pinus albicaulis*). URL: https://www.fs.fed.us/rm/pubs/rmrs_gtr279.pdf
- Conservation and Management of Whitebark Pine Ecosystems on Bureau of Land Management Lands in the Western United States. URL: https://whitebarkfound.org/wp-content/uploads/2016/09/Perkins-et-al.-2016.-Conservation-and-management-of-whitebark-pine-ecosystems.-BLM.pdf
- Restoring whitebark pine ecosystems in the face of climate change. URL: https://doi.org/10.2737/RMRS-GTR-361