Alberta Whitebark Pine Recovery Plan 2013-2018

Alberta Species at Risk Recovery Plan No. 34

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PREFACE

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. Recovery plans establish a basis for cooperation among government, industry, conservation groups, landowners and other stakeholders to ensure these species and populations are restored or maintained for future generations.

Alberta's commitment to the *Accord for the Protection of Species at Risk* and to the *National Framework for the Conservation of Species at Risk*, combined with requirements established under Alberta's *Wildlife Act* and the federal *Species at Risk Act*, has resulted in the development of a provincial recovery program. The overall goal of the recovery program is to restore species identified as *Threatened* or *Endangered* to viable, naturally self-sustaining populations within Alberta. The policy document *Alberta's Strategy for the Management of Species at Risk (2009–2014)* provides broader program context for recovery activities.

Alberta species at risk recovery plans are prepared under the supervision of the Species at Risk Program, Alberta Environment and Sustainable Resource Development. This often includes involvement of a recovery team composed of various stakeholders including conservation organizations, industry, landowners, resource users, universities, government agencies and others. Membership is by invitation from the Executive Director of the Fish and Wildlife Policy Branch and is uniquely tailored to each species and circumstance. Conservation and management of these species continues during preparation of recovery plans.

The Executive Director of the Fish and Wildlife Policy Branch provides these plans as advice to the Minister of Environment and Sustainable Resource Development. Alberta's Endangered Species Conservation Committee also reviews draft recovery plans and provides recommendations on their acceptance to the Minister. Additional opportunities for review by the public may also be provided. Plans accepted and approved for implementation by the Minister are published as a government recovery plan. Approved plans are a summary of the Ministry's commitment to work with involved stakeholders to coordinate and implement conservation actions necessary to restore or maintain these species.

Recovery plans include three main sections: background information that highlights the species' biology, population trends, and threats; a recovery section that outlines goals, objectives, and strategies to address the threats; and an action plan that profiles priority actions required to maintain or restore the *Threatened* or *Endangered* species. Each approved recovery plan undergoes regular review, and progress of implementation is evaluated. Implementation of each recovery plan is subject to the availability of resources from within and from outside government.

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ACKNOWLEDGEMENTS

The Recovery Team would like to acknowledge various individuals for their contribution to the successful completion of this plan. Erica Samis (Alberta Environment and Sustainable Resource Development) initially co-chaired the team and was integral in formulating this document. Laurie Hamilton was an original member of the team and participated in the initial stages of recovery planning on behalf of the Alberta Native Plant Council. The team greatly appreciated reviews of the plan from the following people: Diana Tomback (University of Colorado, Denver), Peter Achuff (Parks Canada Agency), Diane Casimir (Parks Canada Agency), and Michael Murray (B.C. Ministry of Forests, Lands, and Natural Resource Operations). The following Alberta Environment and Sustainable Resource Development staff also reviewed and made helpful comments on the draft plan: Pat Fargey, Ken Greenway, Brooks Horne, Naomi Jehlicka, Dan Lux, and Erica Samis. Drajs Vujnovic and Marge Meijer (Alberta Tourism, Parks, and Recreation) very helpfully compiled and mapped known whitebark pine observations.

EXECUTIVE SUMMARY

Whitebark pine (*Pinus albicaulis*) grows in the high mountain forests of western Alberta at treeline and in upper subalpine forests. Its range in Alberta spans from the U.S. border to the northernmost extent of the Albertan Rocky Mountains. Whitebark pine is a slow-growing, long lived species, often reaching 500 years or more in age. The oldest individual recorded in Alberta was approximately 1100 years old. The tree can grow up to 20 m in height as a single stem but tends to grow in a cluster of stems. At high elevations it takes on a stunted, krummholz growth form. Whitebark pine performs several important ecological functions and is considered both a keystone and a foundation species. Whitebark pine has an obligate relationship with Clark's nutcracker (*Nucifraga columbiana*), its primary seed disperser.

On October 24, 2008, the Minister of Alberta Sustainable Resource Development supported the listing of whitebark pine as *Endangered* under Alberta's *Wildlife Act.* This designation was due to an observed and projected population decline across the species' provincial range, caused by the introduced white pine blister rust (*Cronartium ribicola*) and outbreaks of the mountain pine beetle (*Dendroctonus ponderosae*). The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed the status of whitebark pine and designated the Canadian population as *Endangered*. The species was added to the list of legally protected species under Schedule 1 of the *Species at Risk Act* on June 20, 2012.

In September 2009, the Alberta Whitebark and Limber Pine Recovery Team was established in part to produce a recovery plan for whitebark pine in Alberta. The recovery team includes 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 was also invited to join the team, and although not actively developing the recovery plan, it has been kept advised of progress and has reviewed the draft plan.

The recovery plan has been prepared to guide the management of this *Endangered* species over the next five years and beyond. The long term goal of this plan is:
"To conserve existing populations and habitat while restoring populations across its current and historical provincial range in sufficient numbers to continue functioning in its ecological role."

In line with this goal, four objectives have been established:

1. Reduce the direct mortality of whitebark pine;
2. Develop and introduce white pine blister rust-resistant strains;
3. Conserve genetic diversity; and
4. Manage habitat and natural regeneration.

To help achieve this goal and meet the objectives, nine general strategic approaches are proposed:

1. Population monitoring;
2. Tree and stand protection;
3. Conservation of genetic resources;

4. Habitat management;
5. Education and outreach;
6. Research that will elucidate or facilitate recovery actions;
7. Plan management and administration;
8. Resource acquisition; and
9. Collaboration among agencies, jurisdictions, and stakeholders.

Each general approach will be implemented by actions delineated in this report. The overall goal is to protect and manage whitebark pine and reduce the anthropogenic impediments to its survival. This recovery plan will undergo periodic review during its designated life span of five years, after which it will be updated as needed.

1.0 INTRODUCTION

1.1 Provincial and Federal Status

Whitebark pine (*Pinus albicaulis* Engelm., Order Pinales, Family Pinacea) is designated as an *Endangered* species under Alberta's *Wildlife Act* (Government of Alberta 2010). Alberta's Endangered Species Conservation Committee recommended that this species be listed as *Endangered* to the Minister of Alberta Sustainable Resource Development on September 15, 2008. This recommendation was endorsed on October 24, 2008. The species was listed under Schedule 6 of the Wildlife Regulation on September 9, 2009. The *Endangered* designation was based on an observed and projected population decline across the species' provincial range, caused by the introduced white pine blister rust (*Cronartium ribicola*, Order Pucciniales) and on-going outbreaks of native mountain pine beetle (*Dendroctonus ponderosae*, Hopkins). The *Whitebark Pine Initial Conservation Action Statement* specified that a recovery plan would be prepared within 12 months of the species' listing and that sufficient new resources should be made available to support recovery planning. The action statement advised that Alberta Sustainable Resource Development (now Alberta Environment and Sustainable Resource Development) should enhance cone collection programs (both to find and propagate rust-resistant trees and to conserve genotypic diversity), as well as inventory, monitoring, and research endeavours into the use of the anti-aggregation pheromone, verbenone, to protect trees from mountain pine beetle.

Nationally, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) recommended in April 2010 that whitebark pine be listed as an *Endangered* species in Canada (COSEWIC 2010). The Governor in Council acknowledged receipt of the recommendation on October 27, 2011 and the species was added to the list of legally protected species under Schedule 1 of the *Species at Risk Act* (SARA) on June 20, 2012 (Government of Canada 2012). A national recovery strategy for the species is due by June 20, 2013. The recovery process will be led by the Government of Canada, with involvement by the governments of Alberta and British Columbia. This Albertan plan is intended be a resource to the Government of Canada and to potentially be adopted as an action plan under the national recovery strategy.

1.2 Recovery Plan and Recovery Team

The purpose of this recovery plan (herein, the Plan) is to provide strategies for conservation and restoration for whitebark pine in Alberta. The Plan was prepared by The Alberta Whitebark and Limber Pine Recovery Team (hereinafter, the recovery team), which is composed of individuals knowledgeable about the species, organizations influential in the management and recovery of the species, and stakeholders who may be affected by recovery actions for the species. Recovery team members were selected to provide informed and diverse input to development of the Plan. Although the recovery team works with both pine species, this plan is focused only on whitebark pine.

The Minister of (then) Alberta Sustainable Resource Development created the Alberta Whitebark and Limber Pine Recovery Team in September 2009; the recovery team receives operational guidance and approval from the Executive Director of Fish and Wildlife Policy. The recovery team's primary responsibility is to advise the Minister of Alberta Environment and Sustainable Resource Development on management of this species by outlining recovery strategies and actions in the recovery plan. Alberta Environment and Sustainable Resource Development oversees implementation of the recovery plan by facilitating and encouraging involvement of appropriate and interested parties, including members of the team. The team Co-chairs are responsible for evaluating and reporting on the progress of recovery actions, and updating the recovery plan at the end of its lifespan; the recovery team may be reconvened to assist with the update as necessary.

2.0 WHITEBARK PINE BIOLOGY

2.1 General Biology

Whitebark pine is a slow-growing, long-lived species. Trees often reach ages of 500 years or more with the oldest individual in Alberta recorded at approximately 1 100 years old (Luckman and Youngblut 1999). The tree is small-to-medium sized and can grow up to 20 m in height as a single stem but is often multi-stemmed (from several trees growing close together) (Farrar 1995). At high elevations, on sites exposed to strong winds, it assumes a stunted, krummholz growth form. Single stems can be straight with a conical crown but often multiple stems are curved or twisted with a rounded or irregular crown. Needles occur in bundles of five and are approximately 3 to 9 cm in length (Arno and Hoff 1990; Farrar1995; eFloras 2008). Branches are spreading or somewhat ascending and persist on much of the trunk. New growth is tough and flexible. Young whitebark pine has smooth, thin, pale grey to white bark that can separate into plates as the tree ages (Arno and Hoff 1990; Farrar 1995; eFloras 2008). Whitebark pine may be easily mistaken for limber pine (*Pinus flexilis* James) as their growth forms and bark can be similar when open-growing and they have overlapping distributions in Alberta south of about 52° north. Whitebark generally occurs at higher elevations but the most reliable method of differentiating the two species is through male and female cone characteristics; e.g., whitebark female cones are dark purple to brown and are almost round in shape, while limber pine female cones are light brown and cylindrical.

Similar to other pines, the whitebark pine reproductive cycle takes two years from cone initiation to seed maturity (McCaughey 1994). There is minimal vegetative reproduction (Arno and Hoff 1990). First cone production occurs relatively late at 25 to 30 years of age with sizable cone crops starting at 60 to 80 years of age (McCaughey and Tomback 2001). Female cones range in length from 4 to 8 cm and are situated at the outer ends of the branches near the top of the tree. Male cones are approximately 1 cm in length and are on new growth throughout the canopy (McCaughey and Tomback 2001).

Female cones produce an average of 75 seeds per cycle, each weighing approximately 175 mg each (Tomback *et al*. 2001a). The relatively large seed size coupled with its high nutritional value provides an excellent food source for wildlife as described in Section 2.5 (Ecological Role). Large cone crops are produced at irregular intervals, with individual mature trees producing a mast crop every three to five years (McCaughey and Tomback 2001). Some evidence suggests that large cone crops are produced at a shorter interval in the tree's southern range compared to its northern range (Arno and Hoff 1990).

Whitebark pine is one of five stone pine species traditionally placed in subsection *Cembrae*, section *Strobus*, subgenus *Strobus*, genus *Pinus*, family Pinaceae, and the only one in North America (McCaughey and Schmidt 2001; but see Tomback and Achuff 2010 and references therein). *Cembrae* pines are characterized by five needles per fascicle (needle cluster), wingless seeds retained in cones that are indehiscent (do not split open at maturity) and seed dispersal by birds of the genus *Nucifraga* (family Corvidae), the nutcrackers (McCaughey and Schmidt 2001) (see Section 2.6). The wingless seeds and indehiscent cones preclude dispersal by wind and are considered to be derived by the coevolved mutualism between *Cembrae* pines and nutcrackers (Tomback 1982; Lanner 1996). Limber pine, also listed as *Endangered* in Alberta, is in the subgenus *Strobus* (Tomback and Achuff 2010) and traditionally placed in the *Strobi* subsection. Limber pine has dehiscent cones (i.e., cones split open at maturity) with wingless seeds but still relies on nutcrackers as the main agent of dispersal (Tomback and Linhart 1990).

Whitebark pine seeds are an important food source for many wildlife species aside from nutcrackers (Tomback and Kendall 2001; Lorenz *et al*. 2008). Other notable species that depend on the seeds include: red squirrels (*Tamiasciurus hudsonicus* Erxleben), which cut down whitebark pine cones and store them in middens, sometimes in large quantities; black bears (*Ursus americanus* Pallas), which climb trees and harvest cones directly; and grizzly bears (*U. arctos* Linnaeus), which raid the squirrel middens for whitebark pine seeds (Tomback and Kendall 2001). Red squirrels are considered poor dispersers of whitebark pine seeds because cones are typically harvested before seeds ripen, and stored without extracting the seed (preventing germination owing to unsuitable conditions in the midden), and, ultimately, most seeds are consumed by either squirrels or bears (Lorenz *et al*. 2008). Nutcrackers also harvest and cache immature seeds.

Whitebark pine exhibits an unusual delayed germination strategy that creates a seed bank in the soil (Tomback *et al*. 2001b). Seeds may overwinter for one to three years, waiting for favourable moisture conditions before germinating (Tomback *et al*. 2001b). In addition, as a result of premature harvest by nutcrackers and squirrels, the seed embryos may be underdeveloped (McCaughey and Tomback 2001). When germination occurs, multiple stems may develop from either loss of apical dominance or, most commonly, from several seeds in a nutcracker cache (McCaughey and Tomback 2001).

2.2 Genetics

There is limited information on genetic variation and population differentiation for whitebark pine, particularly for adaptive traits although there is increased recent effort to address this (Bower and Aitken 2008; Mahalovich and Hipkins 2011). To date, most genetic variation studies have used molecular techniques, which have likely underestimated population differentiation due to natural selection for critical adaptive traits important for successful species conservation and recovery work.

2.2.1 General Structure of Genetic Variation

Most studies on population genetic variation in whitebark pine have used molecular markers including monoterpenes (Zavarin *et al*. 1991), allozymes (Yandell 1992; Jorgensen and Hamrick 1997; Bruederle *et al*. 1998; Stuart-Smith 1998; Rogers *et al*. 1999; Krakowski *et al*. 2003) and mitochondrial and chloroplast DNA (Richardson *et al*. 2002; Mahalovich and Hipkins 2011). The objectives of these studies have included determination of the levels of genetic variation for the species, the distribution of variation within and among populations, and relation of patterns to biogeographic processes (e.g., glaciation) and geographic location.

In general, these studies have shown average to above average expected heterozygosity, low to moderate population differentiation, and higher levels of inbreeding than for pines generally (Bower and Aitken 2008). In other words, for whitebark pine compared to other pine species, genetic variation (having dissimilar pairs of genes for any hereditary characteristic) is average to above average, the degree to which populations can be distinguished from one another based on genetic tests is low to moderate, and rates of reproduction between closely related individuals are comparatively high. Population differentiation, although low to moderate, was generally reported as greater across regions than within more localized areas (Bruederle *et al*. 1998; Krakowski *et al*. 2003). The majority of observed variation occurred among individuals within populations rather than among populations, which is generally consistent with evidence for open-pollinated, coniferous species (Hamrick and Godt 1990).

Geographic patterns show higher population differentiation and fewer polymorphic loci for populations colonizing areas covered by Pleistocene glaciers (Jorgensen and Hamrick 1997). Highly significant correlations between observed heterozygosity and latitude and longitude have been reported with heterozygosity generally increasing to the south and east (Krakowski *et al*. 2003). This generally supports the hypothesis that whitebark pine recolonized much of its northern range from glacial refugia in the Washington and Oregon Cascades and Northern U.S. Rockies (Richardson *et al*. 2002; Krakowski *et al*. 2003).

Sampling from the northern Rocky Mountains and Alberta is limited (Stuart-Smith 1998). However, the relatively low to moderate levels of local population differentiation and greater regional differentiation with different structure within regions are consistent with evidence for several glacial refugia and subsequent migration and colonization after glaciation (Richardson *et al*. 2002; Krakowski *et al*. 2003). This pattern is also consistent with inhibited gene flow resulting from geographic isolation (Richardson *et al*. 2002), elevated inbreeding resulting from localized patterns of seed caching by Clark's nutcracker (Bruederle *et al*. 1998; Stuart-Smith, 1998; Krakowski *et al*. 2003) and founder effects and gene loss resulting from genetic drift which is characteristic for small isolated populations (Richardson *et al*. 2002; Bower and Aitken, 2008).

A more recent molecular study (Mahalovich and Hipkins 2011) looking at isozyme as well as mitochondrial and chloroplast DNA found high genetic diversity relative to other conifers and evidence for general random mating unlike other studies which indicated more inbreeding. This study like most others did confirm the general weak genetic differentiation between zones, although it did identify a unique Nevada zone based on mitochondrial DNA and fixation index indicating population differentiation. Other zones could also be identified on the basis of differences in total variation.

2.2.2 Adaptive Genetic Variation

In an attempt to increase information on genetic diversity and geographic population differentiation for phenotypic traits related to local adaptation, Bower and Aitken (2008) established replicated genetic trials across test sites using a range-wide sample of 48 populations. Two and three years following establishment, seedlings showed significant among-population variation for most adaptive traits, with geographic population differentiation being low for growth traits (0.07 to 0.14) and moderate for cold adaptation traits (0.36 to 0.47).

Regional patterns were detectable for height increment, biomass and date of needle flush. There was also regional evidence for clinal variation in date of needle flush which was correlated with frost-free period. Positive correlations were detected between temperature variables and height growth, biomass and spring cold injury. In the south survival was positively correlated with summer precipitation and negatively correlated with summer aridity index. Date of needle flush was positively correlated with aridity in the south.

Thus, based on this study, it appears generally that populations from southern regions tend to be adapted to moisture stress and northern ones to thermal stress. Within regions, there is evidence of clinal variation for adaptive traits.

In a more recent ongoing study (Mahalovich and Hipkins 2011) linking molecular work with common garden studies, adaptive differences and population differentiation were detected for survival, six-year height and late-winter cold hardiness. Traits related to infection by white pine blister rust showed weak population differentiation indicating convergent selection for the same genotype in different environments.

2.2.3. Fine Scale Genetic Variation

Whitebark pine typically regenerates in multi-genet clusters (Linhart and Tomback 1985; Tomback and Linhart 1990; Rogers *et al*. 1999). Individuals within these clusters have been found to be more closely related than individuals from different clusters of the same population (Furnier *et al*. 1987; Rogers *et al*. 1999). Both upper subalpine and treeline tree clusters in three Sierra Nevada watersheds studied by Rogers *et al*. (1999) showed that genetic differentiation among watersheds was negligible whereas the differentiation between the upper subalpine and treeline clusters was modest. Stronger differentiation was found among individual clusters within a sampled site, regardless of elevation. Relationships within treeline and subalpine clusters showed strong family structure with subalpine clusters commonly exhibiting full-sibling (sharing both parents) to selfed (having only one parent; female cones and pollen coming from the same tree) structure while that of upper elevation clusters was somewhat less strongly related – more commonly closer to that of half (sharing only one parent) to full-sibling. This pattern of differentiation is different than local patterns for most pines that are wind-dispersed (Bruederle *et al*. 1998). However, the pattern observed for whitebark pine is consistent with what one would expect for nutcrackers collecting seed and then caching it within typical flight distances of 1-3 km but occasionally over 30 km (Vander Wall and Balda 1977; Rogers *et al*. 1999; Lorenz *et al*. 2011).

2.2.4. White Pine Blister Rust Susceptibility and Genetic Resistance

Whitebark pine is highly susceptible to white pine blister rust (Hoff *et al*. 1980; Sniezko *et al*. 2012) (for more detail, see Section 3.3). High levels of mortality from white pine blister rust have occurred on many sites between 45-52º N, and the disease increases both south and north from these latitudes (Hoff *et al*. 2001; Krakowski *et al*. 2003; Tomback and Achuff 2010).

Studies indicate that whitebark pine has genetic resistance to white pine blister rust (Hoff *et al*. 2001; Sniezko *et al*. 2011) and ongoing resistance screening studies are greatly increasing the number of individuals, families and populations under test (Sniezko *et al*. 2011; Sniezko *et al*. 2012). Although the basis for resistance or distribution of controlling genes is still not well understood, there is evidence for several types of heritable resistance including premature shedding of needles, short shoot resistance to infection, a bark reaction that isolates stem infections and some evidence for slowed canker growth and infection tolerance including progenies that are canker free (Hoff *et al*. 1980; Hoff *et al*. 2001; Sniezko *et al*. 2012). These resistance mechanisms have been detected among families but also show regional patterns (Sniezko *et al*. 2011). Based on information from other soft pines, it may be expected that some major resistance genes will be neutralized by corresponding genes for virulence in white pine blister rust (Kinloch and Comstock 1981; Kinloch and Dupper 2002). Thus, development of resistance strategies must incorporate selective breeding for suites of resistant genes.

There is evidence that where infection rates are high, mass selection of resistant trees from stands with high infection rates or mortality can capture sufficient heritable resistance to support restoration planting and tree breeding programs (Hoff *et al*. 2001; Mahalovich and Hipkins 2011). Although there is no specific information for whitebark pine, Bingham (1983) estimated that about 1 in 10 000 western white pine trees is canker-free in high infection areas, which may provide some guidance for whitebark pine resistance screening work.

In conclusion, whitebark pine appears to be highly variable within populations compared with other conifers indicating that there is sufficient adaptive variation for selection and breeding of resistance to white pine blister rust. Although among population genetic variation tends to be on the low side, there is evidence for population differentiation and genetic clines for adaptive traits. This would suggest that potential regional selection for rust resistance could be effective and that there is a need for seed transfer rules, seed zones and regional sampling for tree gene conservation efforts.

2.3 Habitat

Whitebark pine inhabits high mountain forests in western North America, occupying a narrow elevation zone from treeline to mixed, closed subalpine forests, often on drier, southwestern aspects, although this can vary with latitude (Arno 2001; Arno and Hoff 1990). The trees assume a krummholz (dwarfed) form at treeline where they are exposed to cold, wind and snow, whereas at lower elevations, under more favorable conditions, the stems can be straight and even tall under the most productive conditions (Ogilvie 1990). Whitebark pine trees have been reported to grow over 20 m in height and 70 cm in diameter at lower elevations north of the Crowsnest Pass in Alberta (Day 1967; B.C. Jones pers. comm.).

Whitebark pine may form climax forests, which are self-replacing over time, at treeline and on harsh, exposed sites (Arno and Hoff 1990). Short growing season, poor soils, and aridity are likely the main factors restricting habitat at higher elevations and reducing competition (Weaver 2001). The snowpack often protects whitebark seedlings during winter, but in summer, high temperatures at the soil surface may be lethal to seedlings (Weaver 2001). In the upper subalpine zone, whitebark pine is limited by its ability to compete as a seral species because it is a relatively shade-intolerant tree. In subalpine mixed forests, whitebark pine may be replaced over time by subalpine fir (*Abies bifolia* Murray; most of what was formerly known as *A. lasiocarpa* in Alberta is now known as *A. bifolia*), Engelmann spruce (*Picea engelmannii* Parry *ex* Engelm.) (Weaver 2001). Disturbance such as fire, insects or disease favours regeneration and growth of whitebark pine, initiating successional processes in these seral communities (Arno 2001; Weaver 2001). Conversely, the reduction in fire that results from fire exclusion practices may result in advancing succession in whitebark pine communities. Reduction in disturbance processes results in fewer openings in the forest attractive to Clark's nutcracker for seed caching, and also a reduction in good quality regeneration sites.

Whitebark pine occurs across a broad range of climatic conditions. Extreme temperature ranges in whitebark habitat in the U.S. Rocky Mountains can reach 29°C in the summer to -34°C in winter months (Weaver 2001). However, summers are typically short and cool with July temperatures ranging from 4°C to 18°C (Weaver 2001), thus facilitating a cool growing season with occasional occurrence of frost and snow (Arno and Hoff 1990). Yearly precipitation in U.S. whitebark pine habitats varies considerably with annual means ranging from 600 to 1800 mm mostly in the form of snow (Arno and Hoff 1990).

Whitebark pine prefers well drained sites and typically tolerates poorly developed soils. Parent materials in the Rocky Mountains include limestones, sandstones and shale at varying degrees of weathering (Ogilvie 1990) on glacial till and colluvial landforms. In Alberta, soils that support whitebark pine are typically Orthic Eutric Brunisols, Orthic Regosols and Dystric Brunisols (Ogilvie 1990). Whitebark ecosystem soils are frequently calcareous and basic (Ogilvie 1990) but tend to be more acidic in the Rocky Mountains (COSEWIC 2010).

2.4 Distribution, Population Size, and Trends in Alberta

Fossil evidence indicates that whitebark pine has been present in North American subalpine ecosystems for at least 100 000 years (Baker 2009). During the cooler post-glaciation period from about 10 000 to 15 000 years ago, whitebark pine was more widespread but retreated to higher elevations during the warming Hypsithermal period (8000 to 4000 years ago) (McCaughey and Schmidt 2001). A slight cooling trend about 4000 years ago created the conditions that account for the distribution of whitebark pine today (McCaughey and Schmidt 2001).

In Canada, whitebark pine is found above 1000 m throughout the Coast Ranges (Ogilvie 1990) and above about 1800 m in the southern portion of the Rocky Mountains in British Columbia and the Rocky Mountains in Alberta (Arno and Hoff 1990; Farrar 1995). In Alberta, the northern limit is approximately 150 km north of Jasper, Alberta (Ogilvie 1990) in the Kakwa Wildland Park where the Rockies end in the province. Whitebark pine in Alberta ranges from Kakwa south along the eastern main range of the Rocky Mountains, south through Jasper and Banff national parks, and provincial crown lands (i.e., C5 Forest Management Unit) south to Waterton Lakes National Park (Figure 1). The general distribution of whitebark pine is well established; however, exact locations are poorly mapped (Alberta Sustainable Resource Development and Alberta Conservation Association 2007a).

Whitebark pine forests are typically discontinuous in Alberta, because they are confined to high mountainsides and ridges often being separated by valleys. Stands nearer the Continental Divide tend to be closer in proximity owing to narrower valleys, whereas more easterly stands on lower ridges are more widely separated (Alberta Sustainable Resource Development and Alberta Conservation Association 2007a). This is more so the case from Kananaskis north to Kakwa but less so on provincial crown lands around the Crowsnest Pass. The C5 Forest Management Unit (a provincial crown unit), which covers the Castle, Porcupine Hills and Livingstone areas holds much of the Alberta whitebark population. In the C5, whitebark pine mostly occurs as a seral species in mixed subalpine forests. In the foothills of southern Alberta's eastern slopes, trees lower in elevation may be mistaken for limber pine because they have similar growth form and habitat requirements (Alberta Sustainable Resource Development and Alberta Conservation Association 2007a, 2007b). As whitebark and limber pine can occur in the same stands and limber pine can be found up to 2000 m in southern Alberta (B.C. Jones, pers. comm.), elevation is not a suitable identifying characteristic.

Whitebark pine population size and trends have been recently summarized in two status reports (Alberta Sustainable Resource Development and Alberta Conservation Association 2007a, COSEWIC 2010). The population size of whitebark pine in Alberta has been estimated using a mean of 263 stems/ha from Smith *et al.*'s (2008) blister rust assessment and an area of occupancy estimated at 1099 km^2 based on limited inventory (Alberta Sustainable Resource Development and Alberta Conservation Association 2007a). Summarized in the COSEWIC (2010) report, there are an estimated 28,903,700 mature stems (DBH > 10 cm) in Alberta. However, as a result of poor inventory data on provincial crown lands, this number may be greatly underestimated. It is estimated that there are 169,452,200 mature stems in B.C. for a total of approximately 200 million whitebark pine trees in Canada (COSEWIC 2010).

Whitebark pine is currently declining in Alberta as a result of the combined effects of white pine blister rust, mountain pine beetle, fire exclusion and climate change. These threats are described in detail below in Section 3.0 (Threats and Limiting Factors). Blister rust is the primary threat and substantial data have been collected to determine the rate of population decline in Alberta (COSEWIC 2010; Smith *et al*. 2008; 2013). Based on plots established across the Canadian Rocky Mountains, in 2009 the average rust infection rate of living trees was 52% while mortality was 28% (Smith *et al*. 2013).

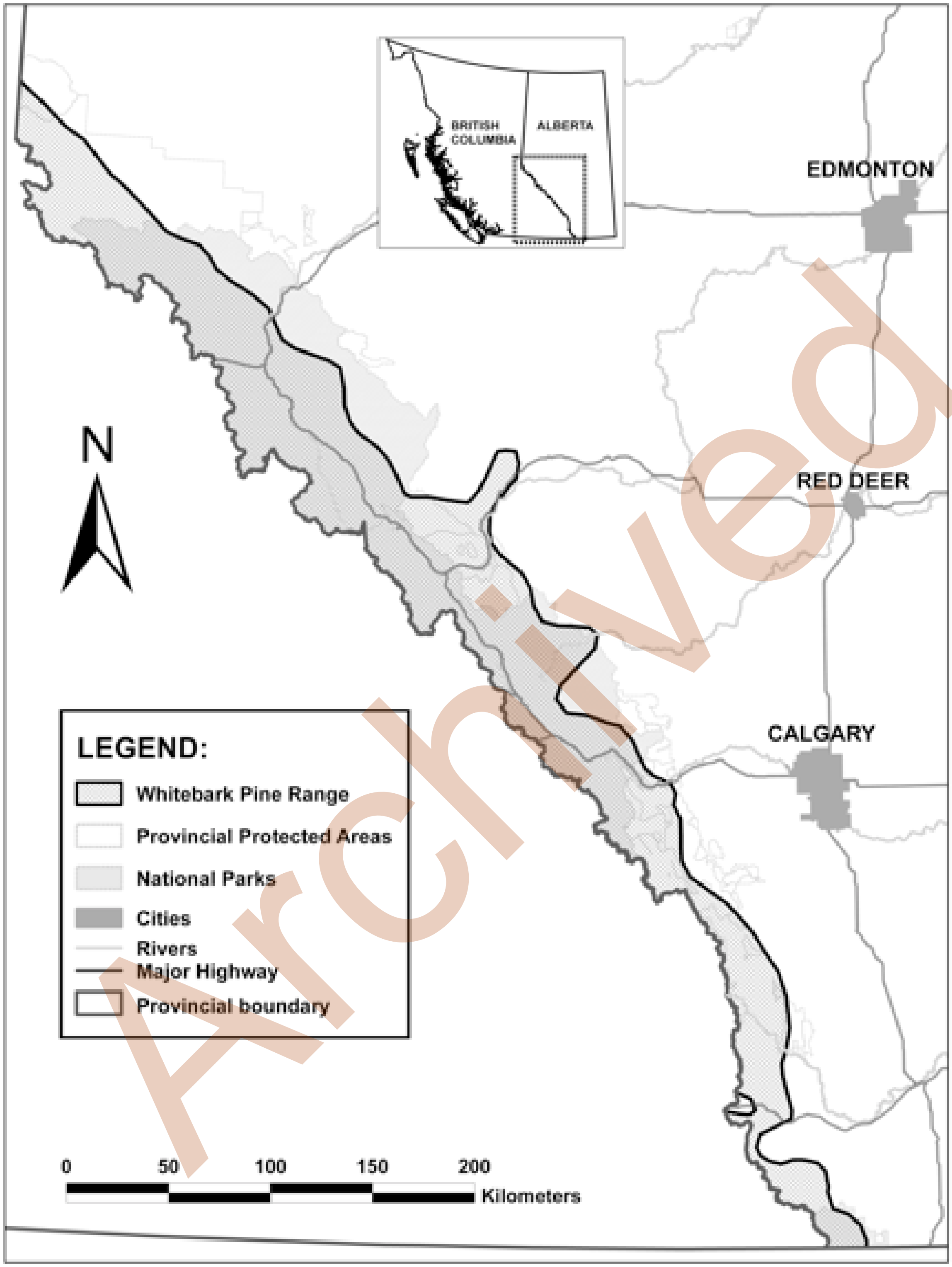

Figure 1. Known range of whitebark pine in Alberta.

However, there is much variability with significantly higher levels of both infection and mortality in southern Alberta. The estimated rate of population decline for the Canadian Rockies is 78% over 100 years; the rate is 97% over 100 years for Waterton Lakes National Park alone (COSEWIC 2010). A rough estimate for the entire Canadian population is a decline of 57% over 100 years (COSEWIC 2010). These population decline estimates assume that the rust infection level and stem canker level are constant over the 100-year period and also that recruitment of mature trees from young trees is negligible.

These estimated rates of decline may be substantially higher if mountain pine beetle-caused mortality of whitebark pine increases from current low levels in Alberta. Climate change is anticipated to promote mountain pine beetle outbreaks in whitebark pine habitat as is currently being observed in the Greater Yellowstone Ecosystem (Logan *et al*. 2010).

2.5 Ecological Role

Whitebark pine performs several important ecological functions and "ecosystem services" throughout its range. For its role in supporting biodiversity, whitebark pine is considered a keystone species (Mills *et al*. 1993; Tomback *et al*. 2001). By promoting community development and stability, it serves as a foundation species (Ellison *et al*. 2005; Tomback and Achuff 2010; Tomback *et al*. 2011). Whitebark pine seeds are a major food source for wildlife and the tree colonizes early after disturbance; promotes community development; reduces soil erosion and protracts snow melt in the upper subalpine and at the treeline; and, at the highest elevations, serves as a tree island initiator in many Rocky Mountain treeline communities. Much of this information is based on research from the United States and, although it has not yet been confirmed whether it applies to all populations in Alberta, until more detailed knowledge is available on Alberta populations, a precautionary approach would assume that for the most part, Alberta whitebark pine could play a similar role.

Whitebark pine seeds are the largest of the subalpine conifers and provide a high value food source for birds, small mammals and bears (Tomback and Kendall 2001) and in particular, whitebark pine has an obligate relationship with Clark's nutcracker, its primary seed disperser (Hutchins and Lanner 1982; Tomback 1982; Lanner 1996). The interactions among whitebark pine, red squirrels and grizzly bears are well established (Mattson *et al*. 1991). Red squirrels harvest cones and store them in middens for later consumption. Grizzly bears forage on seeds from cones taken from these middens. Grizzly bear dependence on whitebark seeds is well established in the Greater Yellowstone Ecosystem (Mattson *et al*. 1991) and to a lesser extent on the eastern front of the Montana Rocky Mountain (Mattson *et al*. 2001). The role of whitebark pine seeds in grizzly bear diet in Alberta, however, remains unclear. Initial research into bear diet in the Willmore Wilderness Park indicates that bears are consuming whitebark pine seeds. Further research using isotope analysis of hair aims to determine to what extent (J. Gould, pers. comm.).

As an early seral species, whitebark pine is often the first species to establish following disturbance such as forest fires or avalanches (e.g., Tomback *et al*. 1990; 2001b). The early establishment of whitebark pine on harsh, high-elevation sites can ameliorate conditions and create microsites for seedling establishment of conifer species, such as subalpine fir and Engelmann spruce, thus facilitating community succession (Callaway 1998; Resler and Tomback

2008). At the treeline, this function is particularly important where whitebark pine initiates krummholz tree islands (Resler and Tomback 2008). These upper subalpine and treeline communities serve to stabilize snowpack. Furthermore, whitebark pine canopies provide shade that delays snowmelt and function in regulating spring runoff (Farnes 1990; Tomback *et al*. 2011). Regulation of runoff reduces erosion of the poorly developed, shallow soils in these upper watersheds (Farnes 1990; Tomback *et al*. 2011).

2.6 Clark's Nutcracker

Clark's nutcracker (*Nucifraga columbiana* Wilson, Order Passeriformes, Family Corvidae) is a jay-sized corvid that resembles a crow in form and flight pattern. Nutcrackers are found in montane and subalpine forests in western Canada and the United States. The Canadian range extends from the eastern slopes of the Coast Ranges through the southern and central interior of British Columbia and into the Rocky Mountains of Alberta (Salt and Wilk 1966; American Ornithologists' Union 1983; Campbell *et al*. 1997). Particularly large numbers of nutcrackers occur in Banff National Park (Taverner 1949; Semenchuk 1992). Most knowledge concerning this bird originates from work done in the United States (Tomback 1998).

Nutcrackers are almost exclusively responsible for whitebark pine seed dispersal. Although the tree depends on the nutcracker for dispersal, nutcrackers also rely on other conifers as a seed source, particularly if whitebark pine fails to produce cones (Tomback and Linhart 1990). Even when whitebark pine seeds are produced, some birds use other seed sources primarily (Lorenz *et al*. 2011). After harvesting whitebark pine seeds, nutcrackers harvest and cache seeds from other conifers and continue caching until about December (Vander Wall and Balda 1977; Tomback 1978; Tomback 2001; Tomback and Kendall 2001). Nutcrackers use their pointed, sturdy bill to tear open cones and extract seeds, and transport seeds within a pouch in the floor of the mouth (sublingual pouch) that can hold over 100 seeds (McCaughey and Tomback 2001). Dispersal by nutcrackers confers an advantage to whitebark pine over wind-dispersed competitors such as spruce and fir. The nutcrackers can carry the seeds much further than they would be carried by wind and can also carry them upwind and either or up or down slope (Tomback *et al*. 1990; Tomback 2001). Nutcrackers typically cache seeds within a few hundred metres of the source tree but can also travel 30 km or more, typically downslope, to distant cache sites (Tomback 1978; Hutchins and Lanner 1982; Lorenz and Sullivan 2009; Lorenz *et al*. 2011). In years of high seed production, a single nutcracker is estimated to cache 32 000 – 98 000 seeds (Hutchins and Lanner 1982; Tomback 1982) but local populations of nutcrackers may only consume about 55% of seeds cached (Tomback 1982). Unretrieved seeds are the source of whitebark pine regeneration.

Understanding the characteristics of seed cache sites, and by extension whitebark pine regeneration sites, is integral for recovery planning. Nutcrackers tend to cache seeds on steep slopes with southern exposure that collect less snow and experience earlier snowmelt (Tomback 1978; Tomback 2001). In this way, the food source is available for a greater proportion of the year. Seeds are cached in a variety of scattered locations and caches are less than 3 cm below the ground, and contain 3 to 5 seeds on average (Tomback 1998; Lorenz *et al*. 2008 and refs. within). Microsites for seed caching vary greatly. They can be next to reference objects such as rocks or trees, but can also be under tree canopies and in open terrain (Tomback 1978; Tomback 2001). Nutcrackers can cache seeds above ground in trees, although typically they cache in sites favourable for whitebark pine regeneration (Tomback 1982; Lorenz *et al*. 2011). Because cache site characteristics vary among nutcracker populations (Tomback 2001; Lorenz *et al*. 2008; Lorenz *et al*. 2011), research within the Albertan range of whitebark pine is necessary to identify sites for restoration opportunities.

Though there is a paucity of data on changes in habitat availability for Clark's nutcracker, the existing threats to whitebark pine (white pine blister rust, mountain pine beetle, competition, climate change) may have had a significant negative impact on overall nutcracker distribution (Tomback 1998). In the long term, the continued decline of whitebark pine will likely result in overall reduction in habitat availability for the species. There is evidence from research in Montana that once cone production and live basal area fall below a certain threshold, a vast reduction in whitebark pine seed dispersal will result (McKinney and Tomback 2007; McKinney *et al*. 2009; Barringer *et al*. 2012). Recent research conducted in Glacier National Park and in Waterton Lakes National Park in comparison with the Greater Yellowstone Ecosystem has demonstrated that in areas of highest white pine blister rust infection: 1) whitebark pine cone production is lowest (Barringer and Tomback 2009); 2) there are fewer nutcrackers (Barringer *et al*. 2012; McKinney and Tomback 2007; McKinney *et al*. 2009); and 3) there is insufficient live basal area of whitebark pine to support seed dispersal by nutcrackers (Barringer *et al*. 2012; Wong 2012).

There is no information about decline in nutcracker population numbers but populations are known to fluctuate from year to year in response to food availability. Nutcrackers preferentially harvest and cache the large, wingless seeds from whitebark and limber pine, which ripen in late August and early September, but then turn to the more widespread ponderosa pine and also use Douglas fir seeds (Tomback 1998). Seed caches are essential to carry the birds through winter and spring and to feed the young. If cone crops fail, Clark's nutcrackers will wander in search of food, starting in late summer. Local populations may decline and have fewer offspring as a result of poor seed production (Bradbury 1917; Mewaldt 1948). Populations appear to recover rapidly from regional declines. Cone crop failure will result in long-distance irruptions (i.e., dispersal events) and likely high mortality of birds in poor condition (Vander Wall *et al*. 1981).

Clark's nutcracker is currently listed as *Sensitive* in Alberta (Alberta Sustainable Resource Development 2011) and is protected provincially as a *Non-game Animal*. It is not listed with special conservation status anywhere else in its range and is not federally listed. Declines in whitebark and limber pine populations in Alberta and other areas of the northern Rocky Mountains may lead to declines in nutcrackers, and possible shifts in distribution. An increased frequency of migration or irruptions in search of food may also occur. Although the bird is able to use other tree resources, a decline in carrying capacity as well as seed dispersal services is likely (Tomback and Kendall 2001). Conservation of whitebark and limber pine in Alberta is important to protect this bird species from decline.

A habitat suitability model was developed for Clark's nutcracker during the Southern Headwaters at Risk Project because of concern over the decline of whitebark and limber pine trees within the study area (Blouin 2004). The outcome of the model was a map showing potential spring to fall habitat (four categories, ranging from least suitable to highly suitable) for the Clark's nutcracker in the study area. It was developed at the landscape scale using coarse variables, and was based on published and unpublished literature and expert opinion.

3.0 THREATS AND LIMITING FACTORS

3.1 Overview

Four main factors affect the survival of whitebark pine: white pine blister rust (an introduced species), range expansion of mountain pine beetle, fire exclusion promoting successional replacement, and climate change (Kendall and Keane 2001; Tomback *et al*. 2001a, Weaver 2001; Wilson and Stuart-Smith 2002). Individually, these factors have can have detrimental effects on whitebark pine, but together, they greatly accelerate rates of decline. Where competition from fir and spruce has excluded younger whitebark, the remaining mature trees have a high probability of rust infection and beetle attack (Kendall and Keane 2001). In addition, there is evidence that whitebark pine stressed by competition, or by rust infection, are more susceptible to attack from mountain pine beetles (Arno 1986; Six and Adams 2007; Bockino and Tinker 2012). These four main factors, combined with three others, are summarized and described below in the context of Alberta whitebark pine stands.

As a consequence of the threats that are outlined below, whitebark pine populations experiencing dramatic decline have high potential for loss of genetic diversity and, therefore, impaired potential for evolutionary resilience as populations reach low levels. This evolutionary resilience is determined by the kind and amount of adaptive genetic variation occurring among individuals within populations of a species as well as genetic variation occurring among populations of the species. There are several ways in which significant mortality can impact the genetic capacity for populations of a species to recover. The first is the reduction of total genetic variation (i.e., a genetic bottleneck) and the second is loss of genes as a result of increased genetic drift which occurs in increasingly small mating populations. These processes, which result in loss of genetic variation, present a challenge for species recovery.

3.2 Threat Assessment

The recovery team undertook an assessment of the threats to whitebark pine based on published information and expert knowledge. For this exercise, the team determined the relative significance of each threat to the recovery and conservation of the species through evaluating the degree to which the threat is affecting or will affect whitebark pine and identifying the probability of occurrence and severity for each threat (Table 1).

Table 1. Whitebark pine threat assessment.

Threat	Effect	Probability (H/M/L)	Severity (H/M/L) (local/ range)[1]
White Pine Blister Rust Infection	Mortality and reduced reproduction of whitebark pine	High	High - range
	Potential Loss of Genetic Diversity	High	Medium - range
Mountain Pine Beetle Infestation	Mortality	Moderate	High - range
	Potential Loss of Genetic Diversity	Moderate	Medium - range
Climate Change	Reduction in current habitat suitability and availability within existing range of whitebark pine.	High	Unknown - range
	Low natural whitebark pine establishment in areas where new habitat becomes suitable	Unknown	Unknown - range
	Emergence of new native and exotic insects and disease that kill or injure whitebark pine *does not include mountain pine beetle	Moderate-high	Unknown
	Altered fire regimes (frequency, severity, size)	Current – Low Future - Medium	High - range
Fire	Loss of climax stands and regeneration potential to fire	High	High - local
	Increased competition in seral stands from lack of low intensity fires	High	High - local
	Lack of stand-replacing fires, resulting in aging lodgepole pine forests, which increases suitable lodgepole pine hosts for mountain pine beetle within flight distance of whitebark pine stands	High	High - local
Loss of Primary Seed -dispersing Agent	Potential loss of Clark's nutcrackers at threshold of low whitebark pine density resulting from death of trees	High	High - range
Habitat Loss/Alteration	Alteration of sites during or following commercial/ industrial activity that inhibits natural regeneration of seedlings	Low	Moderate - local
Commercial/ industrial and recreational activity in whitebark habitat	Removal of trees by commercial/ industrial or recreational activities	High	High - local

[1]Severity is assessed as high, medium or low, and at either the local or Alberta range-wide scale

[2]The definition of "high value" will be refined (see section 6.1.1); the current working definition is "whitebark pine stands with low infection rates, or putatively genetically resistant individuals, both occurring within high infection areas or stands; in addition, healthy, mature, highly-productive cone-bearing trees, either as individuals or in stands, have high value for conservation and protection"

3.3 White Pine Blister Rust

3.3.1 Disease Cycle

Whitebark pine, limber pine and other five-needle white pines (Genus *Pinus*, Subgenus *Strobus*) are highly susceptible to the non-native fungus pathogen *Cronartium ribicola*, which causes the disease known as white pine blister rust. The disease has a complex life cycle which includes five spore stages and alternation between a five-needle white pines and *Ribes* (currants and gooseberries) species. Some *Pedicularis* and *Castilleja* species are also hosts of white pine blister rust (McDonald *et al*. 2006), although their role in the infection of pines is unclear.

Infection of pine is accomplished through basiodiospores from the leaves of the alternate hosts (McDonald and Hoff 2001). Basidiospores are disseminated by wind, but require humid conditions to remain viable.

When basidiospores land on soft pines, fungal hyphae grow through the stomata (pores) of the needles into the phloem (vascular tissue) of the branch and along the branch (McDonald and Hoff 2001; Geils *et al*. 2010). Within one or more years, elongated cankers are produced within the area of infection. In the spring, pycnia, or spermogonia, are formed in living pine tissue along the margins of cankers and these produce sweet droplets containing the sexual pycniospores (spermatia). In late spring, aecia form in the tissue that produced spermogonia. Aecia are whitish blisters that break through the bark and erupt to release orange-yellow, asexual aeciospores. Aeciospores are thick-walled and resistant to desiccation so they are capable of being dispersed by wind hundreds of kilometres in a single year by wind (Mielke 1943; Geils *et al*. 2010). Aeciospores infect only alternate hosts (not pine). Within a few weeks following infection of the undersides of *Ribes* leaves, orange, dome-shaped uredinia are formed, and these produce asexual, orange urediniospores throughout the summer during cool, wet periods. These spores re-infect the same or nearby *Ribes*, or other alternate hosts, thereby spreading the disease. In August, when nights are cooler, hair-like telia are formed, which produce teliospores. The teliospores germinate in place on the alternate host, resulting in production of basidiospores, thereby completing the life cycle.

3.3.2 History of Invasion

Cronartium ribicola is native to Asia but had spread to Europe by the mid-1800s, likely with the aid of humans. The history of its spread in North America is reviewed in Geils *et al*. (2010). The fungus was first detected on the alternate host, *Ribes* in eastern North America in 1898 (Spaulding 1922). It is believed that there were several separate introductions within the following few years as a result of the movement of infected seedlings of eastern white pine, grown in Germany and France, to many locations in northeastern North America (Spaulding 1911). By 1919, the disease had spread to Ontario and Quebec and as far west as Minnesota. The introduction of white pine blister rust to western Canada has been attributed to a single shipment of eastern white pine seedlings from France to a plantation at Point Grey, Vancouver, British Columbia in 1910 (Spaulding 1922) with discovery in 1921. From there, supposedly, the disease has spread throughout most of western Canada and the western U.S. Others, however, contend there were multiple introductions of *Cronartium ribicola* to the Pacific Northwest, most likely through importations of both cultivated *Ribes* and white pine, and that the spread of infection occurred far too quickly to be attributed to the Point Grey introduction (Hunt 2009 and references therein, reviewed in Geils *et al*. 2010).

There are two distinct genetic variants of white pine blister rust in North America, an eastern variant and a western one (Hamelin *et al*. 2000), representing the two major colonization events on the continent.

The disease was first reported from Alberta (on *Ribes*) in 1951 (Canadian Forest Service, unpublished data), and found a year later on limber pine near Table Mountain in the southwest (Bourchier 1952). The first record from whitebark pine in Alberta is from the Crowsnest Pass area in 1953 (Bourchier 1953). The first assessment of the extent of white pine blister rust infection in whitebark pine in the Canadian Rockies occurred in 1971 (Smith 1971). A review of records from Forest Insect and Disease Survey reports and collections showed heavy infection in whitebark pine populations along the continental divide from the Montana border north to southern parts of Kananaskis. Although white pine blister rust infection was also found farther north, all infected populations were on the west side of the continental divide (i.e., in British Columbia) until Jasper National Park, where two populations were infected at about 52º 40' latitude. These were also the northernmost infections observed up until that time. The degree of damage was not measured. By 1996, white pine blister rust was found throughout the range of whitebark pine in Alberta (Stuart-Smith 1998).

<u>3.3.3 Impacts</u>

As white pine blister rust infects the bark and phloem of stems and branches, it creates cankers and destroys the conductive tissue. The most obvious and serious impact of white pine blister rust is tree mortality. Once the fungus spreads to the lower bole, tree mortality is virtually assured. However, branch mortality is also important as it affects cone production and subsequently dispersal of seeds. Branch mortality, particularly the upper third of the crown, typically occurs before the tree itself is killed (McDonald and Hoff 2001). Whitebark pine cones are produced in the upper third of the crown so crown death will mean loss of seed production before tree death (Keane *et al*. 1994). Incidence of infection and mortality of whitebark pine in the Canadian Rocky Mountains is regularly monitored through a network of health transects established between 1996 and 2003 (Smith *et al*. 2013).

In 2003-2004, whitebark pine was assessed for health by Smith *et al*. (2008) in the Canadian Rocky Mountains. White pine blister rust infection was observed throughout the range of whitebark pine in Alberta. Plots sampled in 2003-04 by Smith *et al*. (2008) were reassessed in 2009 and showed that infection rate and mortality had increased throughout the range of whitebark pine (Smith *et al*. 2013). The mean infection level for the combined Canadian Rockies and Alberta protected areas transects is 41.3%; the mean mortality level is 22.1% (COSEWIC 2010). Infection levels of 100% and mortality of 90% were found in some plots (Smith *et al*. 2008). Between 2003 and 2009, infection levels have increased from 42% to 52% (Smith *et al*. 2013) or about 1.5%/year. Eight transects in Waterton Lakes National Park that have been measured three times showed an increase in infection from 43% in 1996, to 70% in 2003, and 78% in 2009. Mortality increased from 26% in 1996, to 65% in 2009 (Smith *et al*. 2013), for a rate of 3.5%/year. Clearly, white pine blister rust is having a measurable impact on whitebark pine, causing widespread damage and mortality, and the condition is expected to worsen.

As seed production is reduced because of canopy kill and tree mortality, red squirrels and Clark's nutcrackers consume an increasing proportion of the existing seed production, thus reducing seed dispersal and possible recruitment. Furthermore, when seed production falls below a certain threshold, Clark's nutcrackers have been shown to no longer use the stands, with subsequent loss of seed dispersal entirely (McKinney and Tomback 2007; McKinney *et al*. 2009; Barringer *et al*. 2012). The low regeneration density of whitebark pine in many severely-infected stands means that mortality now outpaces recruitment of mature cone-bearing trees, resulting in population decline in most stands in the southern half of the range in Alberta.

3.4 Mountain Pine Beetle

3.4.1 Biology

The mountain pine beetle, *Dendroctonus ponderosae* is a native bark beetle of western Canada. Primary hosts in Western Canada are lodgepole pine (*Pinus contorta* Loudon), ponderosa pine and western white pine but mountain pine beetle can infest and kill any native pine including whitebark pine (Safranyik and Carroll 2006).

Mountain pine beetles typically undergo a one-year lifecycle but may take two years to complete development at higher elevations where it experiences cooler temperatures that protract development (Safranyik and Carroll 2006). Most of the lifecycle is completed under the bark of the host tree and adults emerge in late summer to mate and find new hosts. Adult beetles typically disperse within the stand, but an unknown proportion leave the stand for long-range dispersal (Safranyik and Carroll 2006). Trees attacked by mountain pine beetle show visible signs, most notably exuding resin (i.e., pitch tubes) from the tree defense response and a fading crown when foliage turns from green to yellow-red to completely red.

Mountain pine beetle overwhelms a tree's defenses with a mass attack strategy, which involves a complex interaction of beetle- and tree-produced volatile chemicals (Safranyik and Carroll 2006). Attacking beetles chew through the bark and tunnel through the phloem to mate, lay eggs and develop to adulthood. The tree defenses are overcome through cooperative behavior among the attacking beetles and a mutualistic relationship between the beetle and several species of ophiostomatoid (root-colonizing) blue-stained fungi (Safranyik and Carroll 2006; Rice *et al*. 2007). It is unclear what kills the tree, but a combination of beetles tunneling in the phloem and fungi penetrating both the xylem and phloem facilitates tree exhaustion from defense responses and disruption of water transport (Six and Wingfield 2011).

Mountain pine beetle population dynamics are dictated by the availability of susceptible hosts and weather. Beetles prefer large trees, because tree diameter is correlated with bark and phloem thickness, which provides better protection from weather and predators and a better quality food source, respectively (Safranyik and Carroll 2006). Therefore, mountain pine beetle outbreaks in lodgepole pine tend to develop in stands with trees 80 years of age and greater (Shore and Safranyik 1992). A growing proportion of lodgepole pine in this age range across the range of mountain pine beetle has resulted from fire exclusion policies over the last century. For mountain pine beetle populations to increase to epidemic numbers, a sustained period of favourable weather over several years enables beetles to complete reproduction and development during the summer while experiencing low mortality during the winter (Safranyik 1978; Safranyik and Carroll 2006). Climatic conditions over the past 30 years in western Canada have become more favourable to mountain pine beetle and subsequently promoted expansion into higher elevations and more northerly latitudes (Carroll *et al*. 2004). Favorable climate coupled with a homogeneous, aging forest have created conditions for unprecedented outbreaks of mountain pine beetle.

3.4.2 History of Infestation

Historically, mountain pine beetle range extended from northern Mexico to the central interior of British Columbia and from the Pacific coast east to the Black Hills of South Dakota (Safranyik and Carroll 2006). Previous mountain pine beetle outbreaks occurred in Alberta in the mid-1940s and in the late 1970s/early 1980s (Miyagawa 1995). During the 1940s, mountain pine beetle outbreaks in the mountain national parks (i.e. Banff and Kootenay) spread into the Kananaskis region, but mortality to whitebark pine is unknown. Wong (2012) also found increment-core evidence of whitebark pine mortality resulting from mountain pine beetle in the 1920s and late 1950s in Waterton Lakes National Park. The 1970s/1980s outbreak spread up the Flathead Valley from Montana and entered Alberta in the Castle River valley and Waterton Lakes National Park (Miyagawa 1995). High mortality of whitebark pine was observed in stands in the Castle River region (unpublished data, Alberta Land and Forest Service) and there was an estimated 30-40% decrease of whitebark pine canopy in Waterton Lakes National Park (Wong 2012).

Over the past two decades, mountain pine beetle has expanded north in B.C. and northeast into west-central Alberta as a result of a massive and unprecedented outbreak in B.C. that has affected approximately 14 million ha of pine forests (Safranyik *et al*. 2010). During this outbreak, mountain pine beetle first invaded Alberta in the early 2000s and infested much of the western edge of the province along the Canadian Rockies. The infestations extended from the United States border in the south to north of the Peace River region and east to Slave Lake.

Currently, mountain pine beetle population levels are very low in the southwest part of Alberta and most infestations are outside of the range of whitebark pine. The Willmore Wilderness Park continues to experience small infestations but beetle survival is low (B. Horne, pers. comm.). It is estimated that fewer than 5000 whitebark pine trees have been killed by mountain pine beetle in Alberta during the current outbreak (B.C. Jones, pers. comm.). Most tree mortality occurred north and south of the Crowsnest Pass in southern Alberta, and in the Willmore Wilderness Park. However, sporadic mortality was observed throughout its range in Alberta. As part of the Government of Alberta's mountain pine beetle management program, any whitebark pine detected attacked by mountain pine beetle was felled and burned.

3.4.3 Impacts

Mountain pine beetles kill a tree by effectively girdling it as described in 3.4.1. Although lodgepole pine is the typical host in Alberta, research suggests that whitebark pine may be a better host than lodgepole pine, because it produces proportionally more brood (Amman 1982; Bockino and Tinker 2012) and may not have evolved sufficient chemical defenses (Logan *et al*. 2010).

Mountain pine beetle has occurred in high elevation whitebark pine forests for at least 8500 years (Brunelle *et al*. 2008), but the current infestations in western North America pine forests are causing historically unprecedented mortality at an unexpected scale (Safranyik *et al*. 2010; Bentz *et al*. 2011). The warming climate is the predominant factor promoting mountain pine beetle success in whitebark pine habitat. Over the last few decades, warming temperatures have increased the probability of overwinter survival of beetles in high elevation sites and facilitated a one-year life cycle as opposed to the normal two or three years (Amman 1973; Logan *et al*. 2010). This trend is expected to continue, with beetles prospering in whitebark habitat (Logan and Powell 2009). Although mountain pine beetle is currently not a great threat in Alberta whitebark pine habitat, there is ample evidence to suggest that the warming climate may facilitate an increase of mountain pine beetle from either B.C. or endemic populations. Alberta whitebark pine populations are at as great a risk as in the Greater Yellowstone Ecosystem where mortality of mature trees in some stands is over 90% (Logan *et al*. 2010).

Recent research has shown that whitebark pine trees infected by white pine blister rust are preferentially selected by attacking mountain pine beetles (Six and Adams 2007; Bockino and Tinker 2012). Smaller trees not attacked by mountain pine beetle are still susceptible to infection, which may predispose them to attack by mountain pine beetle when they reach cone-bearing age (Bockino and Tinker 2012). Furthermore, mountain pine beetles prefer larger, mature trees which are also the most reproductively active. Therefore, the death of these trees has a disproportionately large impact on stand seed production (Kendall and Keane 2001). Finally, trees resistant to white pine blister rust are highly valuable for whitebark pine conservation and restoration. However, these can also be attacked and killed by mountain pine beetles, thereby reducing conservation options.

3.5 Fire

Fire disturbance is a natural component of successional whitebark pine ecosystems. However, fire plays different roles in different types of whitebark pine communities. Either too much fire or too little fire can be a threat. Fire regimes in whitebark pine habitat appear to be complex and highly variable based on U.S. studies, with mixed-severity fire regimes proving to be the most beneficial (Murray 2007; Campbell *et al*. 2011). Fire frequency is highly variable across the range of whitebark pine (reviewed in Campbell *et al*. 2011). 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 sites, and removes competing vegetation (Arno 2001). However, fire exclusion may not always be important in subalpine forests because the often long fire return intervals typical of these forests far exceed the establishment of fire exclusion policies (Baker 2009; Larson and Kipmueller 2012). This fact has important implications for best management practices. There is little information available on fire regimes in whitebark habitat in Canada. The following is a brief discussion of fire disturbance with reference to mostly U.S. studies.

Whitebark pine can be broadly classified into two successional states facilitated by moisture and temperature gradients: climax and seral (Arno 2001). Climax and co-climax habitat types occur at treeline and in open subalpine systems where whitebark pine occupies harsh sites and thus experiences less competition from other species, such as subalpine fir; under these conditions, it may occur in pure stands (Arno 2001). Major and minor seral forest types are found below treeline in the upper and lower sub-alpine respectively where shade-tolerant trees may eventually dominate (Arno 2001). In Alberta, whitebark pine often occurs in the typical climax and co-climax forests with both open-growing upright forms and krummholz forms nearer the treeline. In the southern portion of the Alberta range, specifically in the C5 Forest Management Unit between the Crowsnest Pass and Highwood Junction, seral whitebark pine forests are common (B.C. Jones, pers. comm.). Canopies of these stands are mostly closed and dominated by lodgepole pine, Engelmann and white spruce, and subalpine fir.

Because whitebark pine occurs in so many community types, each in different successional stages, the landscape is a complex mosaic of whitebark pine communities. The impact of fire disturbance and the role of fire in regeneration can vary greatly among these communities and therefore presents a great challenge for managing whitebark pine in the context of fire disturbance at the landscape level.

The threat of fire to whitebark pine communities is most important in seral forests where too little fire (i.e., fire exclusion) poses a greater threat than does too much fire. Fire exclusion in seral habitat may affect whitebark pine in a number of ways, which are related to successional processes. First, after severe, stand-replacing fires, burned landscapes can be colonized by whitebark pine via seed caching by Clark's nutcracker in the open terrain (Sala *et al*. 2001; Tomback *et al*. 2001b). Seedlings can grow without competition for some time unless the pre-burned stand had a significant lodgepole pine component with serotinous cones (late in developing or blooming; cones that open after a fire) (Campbell and Antos 2003); such is the case in Alberta. Second, whitebark pine is more fire-resistant than its more shade-tolerant competitors, spruce and fir, owing to somewhat thicker bark, higher crowns and deeper roots (Arno and Hoff 1990; Arno 2001). Therefore, over time, suppression of low intensity fire, which whitebark pine usually survives, but fir and spruce do not, can lead to an increase of fir and spruce at the expense of whitebark pine (Murray *et al*. 1998; Kendall and Keane 2001). To illustrate the point, Arno (2001) speculates that successional replacement has moved the lower elevational limit of whitebark pine upslope by 240 m in western Montana, thus removing about 50% of the original habitat area.

In upper subalpine whitebark pine stands, fire disturbance may be less important because of the open forest and less intense competition from spruce and fir (Campbell *et al*. 2011). Severe fires in these communities historically spread upwards from the closed forest (Murray *et al*. 1998). However, exclusion of even low intensity fires in these sites may result in build-up of fuels that can cause higher than normal intensity fires and subsequent tree mortality. Preliminary work by Wong (2008) suggests that fire may not be prevalent in high elevation stands in the northern Alberta Rockies and that competition from subalpine fir and Engelmann spruce is weak. These stands may remain open without fire. Many of the stands of whitebark pine at the northern limit of its range in Alberta are thought to be climax or co-climax types, given the high elevation, proximity to treeline and open nature of the stands (conversation between J. Gould and D. Tomback, Sept 2009). This is supported by stand regeneration studies done by Wong *et al*. (2008). Although treeline stands are similar in southern Alberta, research on stand regeneration has not been performed. The role of fire in the whitebark systems in Alberta is an area in which additional research is warranted.

Wildfire can have detrimental effects on whitebark pine communities in light of the current threats. High-intensity fire can kill mature, cone-producing trees, and low-intensity fire can kill regenerating trees. Although mortality from wildfire is a natural part of whitebark pine ecosystems, as populations decline and fewer healthy cone-producing trees occur on the landscape, fire-caused mortality will have an increasing impact on population growth. Furthermore, mortality of trees that exhibit putative resistance will be particularly detrimental to recovery of the species. Fire also interacts with other threats such as mountain pine beetle and climate change. Fire exclusion can increase competition between whitebark pine and spruce and fir, at least for seral communities at lower elevations. This may stress trees and lead to whitebark pines that are less able to repel beetle attacks, as well as remove the competitive advantage that whitebark pine has in seed dispersal (Keane 2000). Also, without fire, the density of mature trees may be higher, making the forest more prone to beetle attacks, since beetles preferentially attack large, older trees (Kendall and Keane 2001). Finally, climate change models predict a warmer climate with more frequent fires, which may benefit whitebark pine if regeneration sites exist and seed sources remain (Campbell *et al*. 2011; ref. within).

3.6 Climate Change

Whitebark pine is found as a mature tree on topography of every aspect at the northern limit of its range in Alberta (J. Gould pers. comm.). It currently grows at treeline, often with only tundra vegetation or rock and ice above; thus, it is also at the elevational limit of its range in Alberta. However, the factors that control the northern limit of whitebark pine are unknown, so it is difficult to predict how the species might respond to a changing climate.

The climate in Alberta is anticipated to get warmer and wetter with predicted increases in temperature of 3-5^{o}C by 2050 and precipitation of 15% by 2080 (Barrow and Yu 2005). Annual mean temperature in the Northern Rockies is predicted to increase 3-10 °C by the end of the century (Bartlein *et al*. 1997; Bradley *et al*. 2004). This will shrink the range of whitebark pine, as vegetation from lower elevations advancing upslope reduces habitat suitability for whitebark pine. Even if whitebark pine were to migrate upslope, this migration is likely to reduce the area occupied by the species as a result of movement of a vegetation band up a cone-shaped mountain (Weaver 2001). Furthermore, temperature increases of 1-5 °C are predicted to lead to a successional replacement of whitebark pine by Douglas-fir (*Pseudotsuga menziesii*) and lodgepole pine (Romme and Turner 1991). A United States Forest Service bioclimatic model for western North America predicts a 70% decline in suitable habitat for whitebark pine by 2030 and a 97% decline by 2100 (Warwell *et al*. 2007).

There are several characteristics of species that are associated with either greater or lesser expected ability to adapt to the loss or movement of suitable habitat that could be caused by climate change. Species with short generation times and high fecundity, small seeds capable of long distance dispersal, and short generation times, are thought to be able to adapt and migrate relatively quickly in response to climate change whereas species with small population sizes, low fecundity, low genetic variation and long generation times will be least able to adapt (Aitken *et al*. 2008). The large seeds of whitebark pine may be transported up to 30 km by Clark's nutcracker. However, the species is a late-maturing tree, which may hinder its ability to respond to climate change.

Climate change can interact with other threats to accelerate the decline of whitebark pine, such as was described regarding mountain pine beetle, in Section 3.4.3. The interaction with white pine blister rust is less clear. It has been suggested that a dry, cold environment could inhibit the spread of white pine blister rust (Campbell and Antos 2000). However, white pine blister rust has been found at the northernmost limits of whitebark pine range as well as at treeline (Campbell and Antos 2000; Zeglen 2002; Tomback and Resler 2007; Smith *et al*. 2008). The response of white pine blister rust to a changing climate, therefore, is unknown. Rust is present in high elevation krummholz stands of whitebark pine – areas which are likely to be the zone of treeline migration over time in the future (Resler and Tomback 2008).

Interactions with other species may also change with a warmer climate. It is thought that whitebark pine might be outcompeted by subalpine fir if the climate becomes warmer and more humid (Weaver 2001). Larger, more severe wildfires could also affect subpopulations of whitebark pine, but it is unknown whether this affect would be negative or positive. Climate change could potentially lead to the emergence of new native and exotic insects and diseases that kill or injure whitebark pine, but the likelihood of this is, as yet, unknown.

3.7 Loss of Primary-Seed Dispersing Agent

Whitebark pine is dependent on Clark's nutcrackers for seed dispersal. As discussed in section 2.6, there is potential for a local reduction in occurrence by Clark's nutcrackers as live basal area of cone-producing whitebark pine declines from the threats discussed above. As limber pine is under similar threat to whitebark pine, limber pine seeds cannot fill the role to maintain nutcracker populations where the species' range overlap. If live basal area declines over a larger area, as seems likely, the carrying capacity for Clark's nutcrackers represented by the coniferous forests in Alberta would decline, potentially reducing the population size and changing the distribution of the birds. The recent research from Waterton Lakes National Park shows lower cone production, few nutcrackers and insufficient live basal area to support seed dispersal by nutcrackers (Barringer and Tomback 2009; Barringer *et al*. 2012; C. Wong, pers. comm., see also Section 2.6). This suggests that dispersal of whitebark pine seeds may be on the decline, which will impact future regeneration potential.

3.8 Other Threats

There are a number of other potential threats to this species, which on their own are not causing decline, but in concert with the main threats outlined above, could contribute to decline and thus should be minimized wherever possible.

3.8.1 Habitat Loss/Alteration

Unlike most other species at risk in Alberta, habitat loss or alteration is not the main threat affecting whitebark pine. However, given the ongoing declines resulting from other threats, habitat loss or alteration may exacerbate declines and would be particularly detrimental in suitable regeneration sites where resistance to white pine blister rust may potentially emerge. Adverse effects on habitat may include any alteration of sites during or following commercial/industrial activity that could inhibit natural regeneration of seedlings. Loss or alteration could include disturbing/compacting soil and altering hydrology in a way that hampers natural regeneration.

3.8.2 Incidental Removal of Trees during Commercial/industrial or Recreational Activities

The removal of individual trees during activities such as forestry, energy sector development, mining, and recreational trail construction, can occur without attendant alteration of habitat. Such losses exacerbate local population decline and may remove trees that are resistant to white pine blister rust.

3.9 Biologically Limiting Factors

The biology of whitebark pine allows it to survive in extreme habitats and under severe conditions. However, some aspects of its biology make it more vulnerable to the threats discussed above. Late maturation, coupled with its slow regeneration time make whitebark pine particularly threatened by high mortality events, such as fire, insects and disease. Its sub-alpine habitat is threatened by climate change which predicts in-growth from lower elevation forests. Whitebark pine is reliant on Clark's nutcracker for seed dispersal, which is itself a habitat specialist. This suite of biological traits makes whitebark pine particularly susceptible to cumulative effects from the threats described above.

4.0 CRITICAL HABITAT

The identification of critical habitat is done as part of the preparation of a federal recovery strategy. The whitebark pine federal recovery strategy is currently in preparation so critical habitat data do not yet exist. There are many recovery activities either underway or identified in this plan that may contribute information to critical habitat identification.

5.0 RECENT RECOVERY AND CONSERVATION EFFORTS

Information on the broad geographic distribution of whitebark pine in the province is fairly complete, but information on stand locations is more limited. In recent years, health assessment plots (Smith *et al*. 2008; K. Ainsley and A. Benner, unpublished data, Gould *et al*., unpublished data) and aerial surveys (J. Gould and C. Wong, unpublished data) have contributed location information. A remote sensing project to identify stands was undertaken in Waterton Lakes National Park (McDermid and Smith 2008). Health assessment plots in the province have been established since 2003 by a number of agencies to monitor changes in white pine blister rust infection rates (see Table 2; see Section 3.3.3).

The anti-aggregant pheromone Verbenone (trimethyl-bicyclo-heptenone), and green leaf volatiles that mimic deciduous trees, have been used to protect whitebark pine against attack by mountain pine beetle. Individual trees protected by this methods include phenotypically-blister rust-resistant seed-producing whitebark pine trees, known as “plus trees” (Smith and Backman 2006), as well as whole stands particularly in areas where fire has left isolated stands that could be vulnerable (Horne 2007).

Seed collecting for genetic testing and *ex situ* (off-site - outside a species’ natural habitat) gene banking has been undertaken by Alberta Tree Improvement and Seed Centre since the mid-1970s (L. Barnhardt, pers. comm.), and by Parks Canada since 2006 (Smith and Backman 2006; Parks Canada 2009). Both bulk and single tree collections have been made. Seeds from plus trees have been included in the U.S. Forest Service’s blister rust screening program at the Coeur d’Alene Nursery in Idaho (C. Smith and L. Barnhardt, pers. comm.). This is a 5-7 year trial to determine blister rust resistance. Leslie and Wilson (2011) undertook germination trials to determine optimal late-summer seed collection times.

Restoration planting projects have been undertaken in southwestern Alberta. One project was a grassroots effort in the Castle Special Management Area to collect seeds locally, and then plant them directly in the ground, using different treatments (seed nicked, un-nicked, protected, etc.) (Reg Ernst, pers. comm.). Between 2009-2011, Waterton Lakes National Park planted over 4500 whitebark pine seedlings that varied in age from 2-4 years old (C. Smith, pers. comm.). Some of the seedlings have been inoculated with ectomycorrhizal fungi that may improve their health and survival (Cripps *et al*. 2008).

Other projects that are more research-oriented, such as nutcracker studies and the use of squirrel middens by grizzly bears, are described in Table 2.

Policy changes have been implemented for forestry operations in whitebark pine habitat. Timber companies operating in the C5 Forest Management Unit must follow the Spray Lakes Sawmills and C05 Operating Ground Rules (May 2012) that specify that whitebark pine can only be destroyed when unavoidable, and written approval from ESRD is required. Operating standards for upstream oil and gas were developed for ESRD’s Enhanced Approvals Process.

Table 2. Summary of current and recent conservation efforts in Alberta.

Objective of Project	Who	Where	When	Citation
Seed collecting	Alberta Tree Improvement & Seed Centre	Throughout AB range	Since 1970s	L. Barnhardt, pers. comm.
Health transects	Parks Canada	U.S. border to McBride, B.C., in & outside of protected areas	2003-2004	Smith *et al.* 2008
Health plots; resilience & competition	Carmen Wong, University of British Columbia	Waterton Lakes & Jasper national parks, Willmore Wilderness Park	2005-2009	Wong 2012
Health transects	Alberta Parks	Willmore Wilderness Park, Siffleur & Whitegoat wilderness areas, Plateau Mountain	2005-2009	K. Ainsley and A. Benner, unpub. data
Health plots	Reg Ernst and Peter McTaggart	Castle Special Management Area	2006	Ernst 2006; McTaggart 2007
Fire & regeneration	Randy Moody, University of B.C.	Jasper National Park and Manning Provincial Park, B.C.	2006	Moody 2006
Timing of cone collection & germination success	Adrian Leslie	Banff National Park	2006	Leslie & Wilson 2011
Verbenone protection of stands	ESRD, Forestry	Willmore Wilderness Park. Kakwa Wildland	2006-2011	Horne 2007; B.C. Jones, pers. comm.
Collecting seed from plus trees	Parks Canada	Waterton Lakes National Park	2006-ongoing	C. Smith, pers. comm.
Verbenone protection of plus trees	Parks Canada	Waterton Lakes National Park	2006-ongoing	Smith & Backman 2006
Planting of seeds	Reg Ernst	Castle Special Management Area	2007	R. Ernst, pers. comm.
Remote sensing predictive habitat mapping	Iain Smith, University of Calgary	Waterton Lakes National Park	2007	McDermid & Smith 2008
Clark's nutcracker & cone production	Lauren Barringer, University of Colorado, Denver	Waterton Lakes National Park and U.S. parks	2008	Barringer *et al.* 2012
Health transects	ESRD-Forestry	Crowsnest Pass	2008-2009	B.C. Jones pers. comm
Squirrel midden surveys for grizzly bear use	Foothills Research Institute	Willmore Wilderness Park, Jasper and Banff national parks, Siffleur Wilderness Area	2008-2009	McKay & Graham 2009a, 2009b
Clark's nutcracker use & stand health	Jennifer Scott, University of Colorado, Denver	Waterton Lakes National Park and U.S. parks	2009	Scott *et al.* 2011
Health transect re-measurement	Parks Canada	U.S. border to McBride, B.C., in & outside of protected areas	2009	Smith *et al.* 2011
Ectomycorrhizal fungi research and inoculation of seedlings	Cathy Cripps, Montana State University and Parks Canada	Waterton Lakes National Park	2009-2011	Cripps *et al.* 2008

Objective of Project	Who	Where	When	Citation
Mountain pine beetle life histories in whitebark vs. lodgepole pine	Evan Esch, University of Alberta	Willmore Wilderness Park	2009-2012	Esch 2012
Planting potentially rust-resistant seedlings	Parks Canada	Waterton Lakes National Park	2009-ongoing	C. Smith, pers. comm.
Climate history from whitebark pine	David Sauchyn, University of Regina	Throughout AB range	Unknown	Sauchyn 2010
Regeneration in whitebark stands	Alana Clason	Willmore Wilderness Park	2010-ongoing	J. Gould, pers. comm.
Genetic screening for blister rust	USDA Forest Service	Waterton Lakes National Park & various provincial sites	2010-ongoing	C. Smith & L. Barnhardt, pers. comm.
Use of squirrel middens by bears	Parks Canada	Banff National Park	2011-2012	Forshner *et al.* 2012
Blister rust at treeline	Lynn Resler, Virginia Technical University	Banff National Park, Willmore Wilderness Park	2011-ongoing	J. Gould pers. comm.
Establishment after fire	Brendan Wilson, Selkirk College	Banff National Park	Ongoing	Wilson 2011

6.0 KNOWLEDGE GAPS AND RESEARCH PRIORITIES

There are some important gaps in knowledge about whitebark pine biology, management, and threats. If unaddressed, these gaps will impede recovery efforts. These gaps can only be filled with targeted research and information synthesis. Nonetheless, recovery planning should continue despite these gaps, with adaptation of planning as more information becomes available. Research should be encouraged by making this list available to universities and other research institutions.

The following suggested research is organized based on high, moderate, and low priority, and directly links to recovery action priorities summarized in Table 3.

6.1 High Priority

6.1.1 Inventory of Whitebark Pine Distribution, Population Sizes and Community Types

- Complete a detailed distribution map and inventory using aerial and targeted ground survey data; stratify by region;
- Analyze change in populations and/or habitats through the use of photographs from early surveys and/or old air photos;
- Collect data to facilitate classification of whitebark pine community types;
- Determine detailed, operational criteria for designating trees and stands as “high value;” the current working definition is that high-value refers to whitebark pine stands with low

infection rates, or putatively genetically-resistant individuals, both occurring within high infection areas or stands; in addition, healthy, mature, highly-productive cone-bearing trees, either as individuals or in stands, have high value for conservation and protection; and
- Synthesize and assess data and information from various research initiatives (genetic resistance and tree health, identification of critical habitat and surveys of genetic variation) to identify stands that are of high priority for protection and recovery.

6.1.2 Identification, Testing and Propagation of Genetically-resistant Stock
- Identify potentially-resistant phenotypes and screen for genetic resistance; and
- The potential influence of habitat features and environmental variables on infection, transmission and resistance should be factored into experimental design and field testing.

6.1.3 Understand Cone Phenology
- Examine phenology of cones to determine:
    - Maturation rates of cones and seeds and viability of seed throughout Alberta range;
    - Scope and extent of delayed germination in context of Alberta; and
    - Rates of germination in relation to delayed maturation.

6.1.4 Characterization of Regeneration Sites
- Characterize preferred cache sites of Clark's nutcracker and subsequent regeneration niche of whitebark pine in sites of different origin (e.g., fire, timber harvest);
- Examine the role of competition from other tree species for regeneration across an elevational and latitudinal gradient; and
- Examine the impact of various types of disturbance (e.g., fire, timber harvest) on regeneration and survival at the tree and stand level across an elevational gradient.

6.1.5 Current and Future Habitat for Whitebark Pine
- Develop and update predictive habitat models for mature and young whitebark pine under existing and future climate change scenarios by using current habitat parameters (e.g., soils, climate, biological interactions).

6.1.6 White Pine Blister Rust Research
- Conduct health assessments every 5 years from gradient of health transects;
- Assess white pine blister rust incidence, impacts on whitebark pine survival, and assess rates of change;
- Relate assessments to key climate factors; and
- Collect other relevant data needed for a population viability analysis and compare results to populations further south.

6.1.7 Determine Causes of Differing Infection Rates in Alberta Rockies
- Analyze health transect data to determine factors associated with patterns of disease/infection and determine if additional data are required; also determine if larger scale factors are important.

6.2 Moderate Priority

6.2.1 Genetic Diversity

- Characterize genetic diversity and structure of white bark populations in Alberta including identification of unique genotypes.

6.2.2 Ecological Relationship between Clark's Nutcracker and Whitebark Pine

- Determine impact of reduced cone/seed production on populations of Clark's nutcracker;
- Determine effect of mast and non-mast years on population numbers of Clark's nutcracker; and
- Examine the importance of whitebark pine seeds in the diet of Clark's nutcracker in relation to other potential food sources.

6.2.3 Current and Future Habitat for Clark's Nutcracker

- Determine habitat requirements of Clark's nutcracker for feeding, seed caching and reproduction;
- Develop and model current and future habitat availability; and
- Develop population monitoring protocols.

6.2.4 Mycorrhizal Fungi Associations

- Document mycorrhizal associates of whitebark pine throughout Alberta range;
- Assess effect of geography and/or habitat characteristics on mycorrhizal associations; and
- Investigate the role of mycorrhizal associations in the germination of whitebark pine seeds and establishment of seedlings.

6.2.5 Age of Maturity

- Determine age of maturity (cone production) for populations in Alberta.

6.3 Low Priority

6.3.1 Alternate Hosts of White Pine Blister Rust

- Determine importance of species other than *Ribes*, particularly *Castilleja* and *Pedicularis*, as alternate hosts for white pine blister rust in Alberta; and
- Determine the distribution of alternate hosts.

6.3.2 Determine the Role of other Agents in Decline of Health

- Determine whether agents other than white pine blister rust and mountain pine beetle, such as mistletoe, also account for the decline of whitebark pine health.

6.3.3 Non-lethal Impacts of White Pine Blister Rust

- Determine whether white pine blister rust infections that do not kill the tree affect number and size of cones and seeds, and seed viability.

6.3.4 Hybridization Between White Pine Blister Rust and *Comandra* Blister Rust

- Assess relative pathogenicity of hybrids between white pine blister rust and *Comandra* blister rust. This should include an examination of the impacts on the alternate hosts of white pine blister rust.

6.3.5 Determine Importance of Seed Predators

- Examine extent of seed predation and effect on reproductive potential.

6.3.6 Conduct isotope analysis on grizzly bear hair

- Determine significance of whitebark pine seeds in diet of grizzly bear and relate to research from the United States.

7.0 RECOVERY STRATEGY

7.1 Biological and Technical Feasibility of Recovery

Whitebark pine does not reproduce until 30-50 years of age (see Section 2.1), and does not produce any sizeable cone crops until 60-80 years of age (McCaughey and Tomback 2001; Ettl and Cottone 2004). Thus, recovery actions are necessarily decadal in length. While there has been no significant loss of habitat in Alberta, habitat quality in some areas may have been reduced as a result of fire exclusion, which affects availability of habitat for regeneration.

There are populations of whitebark pine in British Columbia and the U.S. that are contiguous with those in Alberta. Seed dispersal by Clark's nutcracker from those populations to suitable habitat in Alberta is possible, but improbable. The closest populations in Montana and southeastern British Columbia have also suffered drastic declines (Campbell and Antos 2000; Zeglen 2002; Smith *et al*. 2008). The effects of these reduced whitebark pine populations on Clark's nutcracker are uncertain, but their numbers can be expected to decrease given the nutcracker's strong relationship with whitebark pine (Tomback and Kendall 2001), thus decreasing seed dispersal (Siepielski and Benkman 2007). Thus the likelihood of rescue from British Columbia or Montana is extremely low.

Testing of whitebark pine for genetic resistance to white pine blister rust has advanced over the last decade both technically and in outcome (Sniezko *et al*. 2011), following the model for western white pine (*Pinus monticola*) (Hoff *et al*. 2001). In the U.S., work is still in progress on identifying resistant genes, but a diverse pool of source trees from a number of National Forests have been screened for rust resistance, and resistant trees are being protected from mountain pine beetles with verbenone. These trees are providing seed collections for growing rust-resistant seedlings for outplanting within the U.S. Rocky Mountains and Northwest, according to seed transfer guidelines. The USDA Forest Service, Forest Health Protection, has spent millions of dollars to date through the Whitebark Pine Restoration Program, with the outcome of hundreds of planted acres, seed orchards in development, and various thinning and prescribed fire programs (D. Tomback, pers. comm.).

Guidelines for developing restoration strategies for whitebark pine as well as prescriptions and protocols for different restoration treatments are available, which will facilitate plans for recovery (Wilson and Stuart-Smith 2002; Schoettle and Sniezko 2007; Shoal *et al*. 2008; Keane *et al*. 2012). Information is available on collecting cones for seed (Ward *et al*. 2006), growing seedlings in a greenhouse (Burr *et al*. 2001) and planting the seedlings into natural stands (Scott and MacCaughey 2006) as well as seed transfer (Bower and Aitken 2008), enhancing resistance to white pine blister rust (Hoff *et al*. 2001; Burns *et al*. 2008), and re-introducing fire disturbance (Keane and Arno 2001; Arno and Fiedler 2005). Therefore, sufficient information exists to support and direct recovery in Alberta. In addition to the USDA Forest Service, the Whitebark Pine Ecosystem Foundation is a rich source of information and support. Made up of government and academic researchers, the foundation is the focal point for whitebark pine recovery in North America.

The recovery of whitebark pine in Alberta is biologically and technically feasible, but the recovery time frame is over several decades. However, there are several shorter-term actions that can be, and need to be, taken to begin moving toward the long-term goal.

7.2 Guiding Principles

The conservation and management of whitebark pine in Alberta will be guided by the following principles:

- Recovery Team members believe that the recovery of whitebark pine is both desirable and achievable and will commit to working together to achieve this goal.

- All land users and managers within the distribution of whitebark pine, including all affected branches of government, will be strongly encouraged to share responsibility for and support the goal of whitebark pine recovery.
- The team recognizes that humans engage in activities that contribute to economic growth in certain areas where whitebark pine occur. Members will work collaboratively and cooperatively with land managers, landowners, industry and other agencies to ensure, to the extent possible, that recovery initiatives are compatible with sustainable land uses.
- The loss of essential habitat and populations of whitebark pine is undesirable and should be minimized.
- Recovery actions will embrace an ecosystem-based management approach whenever possible.
- Members will adhere to the precautionary principle. Lack of information or scientific uncertainty should not impede implementation of actions believed to be necessary to achieve the goals of this recovery plan. Whenever possible, the collection of data and scientific study of whitebark pine and management outcomes are desirable.
- The recovery process will be guided by the concept of adaptive management, whereby specific actions are implemented, evaluated, and revised upon on an iterative basis.

- Land managers and other cooperators in the management of whitebark pine should be recognized for their contributions towards achieving recovery goals.
- Land managers and other cooperators will not be unfairly affected by the costs associated with recovery measures aimed at whitebark pine. The intention is that no single agency or person will be solely responsible for funding the recovery measures/implementation of this plan. However, costs also include the costs associated with inaction.

7.3 Recovery Goal

The Alberta recovery goal for whitebark pine is to conserve existing populations and habitat while restoring populations across its current and historical provincial range in sufficient numbers to continue functioning in its ecological role.

As a result of uncertainty around how many individuals/populations of whitebark pine currently exist, the severity of white pine blister rust infection, and the high rates of decline, it is not presently considered appropriate to set objectives pertaining to the abundance of mature individuals in Alberta.

7.4 Recovery Objectives

7.4.1 Reduce Direct Mortality

- By 2015, have collected sufficient inventory such that land managers are informed to mitigate loss from mountain pine beetle and fire; and
- By 2014, prevent mortality from sources that can be managed (e.g., industrial/commercial development, recreational), for whitebark pine classified as high value (see Section 6.1.1).

Successful recovery of whitebark pine will require that losses of trees are minimized. This will be especially important for mature cone-producing trees and plus trees (i.e., apparent rust resistance), the latter of which may be rare and may have the potential to provide the material for propagation of white pine blister rust-resistant trees. Furthermore, minimizing mortality prevents genetic erosion at the population level. This objective refers predominantly to mortality caused by mountain pine beetle and fire but also to incidental death of whitebark pine trees from commercial/industrial or recreational activities (e.g., forestry/energy sector/ mining/ recreational trail development).

7.4.2 Develop and Introduce White Pine Blister Rust-resistant Strains

- By 2015, develop germination and stock-rearing protocols and develop an effective screening program for wild candidate stands, both susceptible (stands with white pine blister rust infection that contain a few less-affected or unaffected trees, from which putatively resistant individuals can be selected) and resistant (relatively unaffected stands within areas of higher infection rates, i.e., putatively resistant populations), for material (seed and scion – detached shoots that are used in grafting) collections.

The mortality rate from white pine blister rust is extremely high and the disease has spread across the Alberta range of whitebark pine with few exceptions. The only trees likely to survive are those that are resistant to white pine blister rust or escape infection. Therefore, the only way to maintain this species on the landscape in the long term will be to engage in landscape-level management practices that maximize the opportunity for success of *in situ* (in position - within a species' natural habitat) natural selection supplemented by development and introduction of white pine blister rust-resistant whitebark pine strains.

7.4.3 Conserve Genetic Diversity

- By 2015, increase seed collections and storage, develop germination and rearing protocols, and identify suitable sites for clone banking.

As a first step, there needs to be a systematic seed collection effort based on the Natural Regions and Subregions of Alberta and their nested seed zones. The best approach is to use the ecological stratification in conjunction with inventory and genetic information, particularly as new information becomes available. This integrative approach will most effectively capture existing genetic variation.

Bulk population collections as well as single tree seed and scion collections should be made. Single tree selections should include random population samples as well as individual parent tree selections from trees with putative white pine blister rust and mountain pine beetle resistance These *ex situ* activities will provide genetic materials for conservation archiving, scientific studies, future breeding and for screening, propagation and deployment of putatively resistant restoration stock (see 7.4.2). The scope of this work is limited and should specifically address survival, reproductive vigour and white pine blister rust resistance.

In situ reserves should be carefully chosen to protect them to the extent possible from environmental threats as well as buffer them from potential climate change impacts. This should be accompanied by restoration plantings into strategically targeted populations to keep population numbers up and to aid the process of natural selection and adaptation to the altered biotic and abiotic environment being experienced.

7.4.4 Manage Habitat and Natural Regeneration

- By 2016, generate sufficient data for characterizing regeneration sites in Alberta, by supporting research within government and the academic research community so that operational restoration projects can be undertaken in locations most likely to be successful.

The management of whitebark pine habitat and, subsequently, sites for regeneration, is vital for successful recovery. There are several aspects to this broad objective. First, the role of fire and other disturbance in creating potential caching sites and reducing competition from other species must be better understood. This point includes managing the unintended consequences of excluding disturbance such as aging lodgepole pine forests that can be a source of mountain pine beetle. As wildfire will continue to be excluded from the landscape and not play the role it did historically, working closely with fire managers to find opportunities to use prescribed fire will be essential. Second, natural regeneration should be enhanced by growing stock and planting it out, particularly stock from parents that show putative resistance to white pine blister rust (Section 7.4.2). Finally, natural regeneration to counter the current high mortality rate will only be successful with healthy populations of Clark's nutcrackers. Therefore, knowledge of nutcracker ecology must be improved, including understanding of characteristics of sites required for seed caching.

7.5 Recovery Strategies

Recovery actions for whitebark pine are organized under the following strategic approaches, which will be pursued concurrently over a five-year period:

7.5.1 Population Monitoring Inventory and Assessment)

The population monitoring strategy includes activities relating to assessment of population size and distribution, regeneration success, and health of whitebark pine in Alberta. These efforts are required in order that management can be effectively applied where and when it is most needed.

7.5.2 Protection of Whitebark Pine Stands and Individual Trees

The protection strategy aims to reduce the decline and death of whitebark pine from fire, mountain pine beetle and mechanical removal. These efforts will help maintain viable wild populations and conserve important genotypes through the protection of cone-bearing trees.

7.5.3 Conserve Genetic Resources and Deploy Rust-resistant Whitebark Pine

This strategy relates to genetic conservation, collection, selection, screening, testing, breeding and planting of growing stock. Given ongoing and precipitous declines, mainly resulting from white pine blister rust, recovery will not be successful without implementing this strategy.

7.5.4 Habitat and Natural Regeneration Management

The habitat and regeneration management strategy includes all activities related to monitoring and improving habitat quality and regeneration success both under the current climate regime and in the context of climate change. This includes actions to preserve the role of Clark's nutcrackers in regeneration and other topics related to seed fate.

7.5.5 Education and Outreach

This strategy includes all activities related to educating land managers, landowners/ leaseholders, industrial and commercial stakeholders, recovery partners, and the general public about the conservation and management of whitebark pine in Alberta. The focus will be on preventing the degradation or loss of habitat, expanding awareness of the ecological importance of whitebark pine and related conservation issues, ensuring that stakeholders are informed of local recovery initiatives and their results, and gaining support and participation in management activities.

7.5.6 Research

Most recovery strategies require research to achieve success and a set of research priorities has been developed (Section 6.0). This strategy includes all activities to communicate research needs to those who can fill the needs and engage partners to pursue research questions.

7.5.7 Plan Management and administration
This strategy includes all activities related to the operation of the Alberta Whitebark and Limber Pine Recovery Team, and implementation of the *Alberta Whitebark Pine Recovery Plan 2013-2019*. A key element of this strategy is to build linkages with other provincial, national and international initiatives that will benefit whitebark pine conservation in Alberta.

7.5.8 Resource acquisition
This strategy includes all activities related to securing funding and other resources needed to support the recovery actions detailed in this plan.

7.5.9 Collaboration
This strategy includes all activities related to leveraging expertise and funding through collaboration among various agencies and jurisdictions in Canada and the U.S. that have a common interest in the conservation and protection of whitebark pine. The actions around this objective are not explicitly listed in Section 8.0 as collaboration is an integral part of all actions.

8.0 ACTION PLAN

Numerous actions are needed to achieve recovery of the Alberta whitebark pine population to meet the goal and objectives identified in this plan. They are categorized here by recovery objective. Priorities and costs for each action, as well as a timetable, are detailed in Section 9.0.

8.1 Population Monitoring

1. Map and inventory current distribution of whitebark pine in Alberta;

2. Re-assess health data on established plots every 5-6 years; re-establish transects where necessary;

3. Collect data to facilitate classification of whitebark community types;

4. Collect data required for a population viability analysis (PVA) and compare results to populations outside of Alberta;

5. Annually map mountain pine beetle infestations in areas with whitebark pine;

6. Establish data collection standards and a database(s) for inventory, health transect and community type data; enter whitebark pine data into database(s). Analyze data to determine factors associated with patterns of disease/infection;

7. Support development of predictive habitat models for current and future habitat throughout range, incorporating climate change scenarios. Support other related initiatives;

8. Synthesize and assess data and information from various research initiatives (genetic resistance and tree health, identification of critical/essential habitat and surveys of genetic variation) to identify stands that are of high priority for protection and recovery;

9. Establish criteria for designating stands as "high value," and for identifying putatively resistant trees;

10. Establish pre- and post-treatment plots and protocols to monitor response of whitebark pines at select sites where it will be or has been burning or harvesting has occurred and also sites where competing vegetation has been or will be removed;

11. Determine whether white pine blister rust infections that do not kill the tree affect number and size of cones and seeds, and seed viability;

12. Analyze change in populations and/or habitats through the use of photographs from early surveys and/or old air photos;

13. Survey insects and diseases currently feeding on live whitebark pine trees and assess potential for significant impact in the future, especially under climate change;

14. Monitor and report insect and disease problems in permanent sample plots and research plots with a whitebark pine component;

15. Engage with existing initiatives (e.g., integrated pest management group, citizen science initiatives) to facilitate early detection of plant health problems; and

16. Carry out a seed zone review to determine flexibility for seed collections and deployment based on genetic information.

8.2 Protection of Whitebark Pine Stands

1. Once criteria for "high-value" trees and stands is determined, when these sites are identified they should be protected as *in situ* reserves and seed-production stands;

2. Remove individual mountain pine beetle-infested lodgepole pine trees in or near high-value whitebark pine stands;

3. Deploy semiochemicals (e.g., verbenone) in high-value stands as appropriate to deter mountain pine beetle;

4. Communicate to fire managers the locations of high-value stands as well as the team's expectations as to the protection of these identified stands;

5. Exclude, or adequately protect, high-value whitebark pine stands in burn units;

6. Assess wildfire risk in high-value WBP stands;

7. Work with fire and forest managers to identify and manage high-risk lodgepole pine stands that could be a source of mountain pine beetle or wildfire, posing a risk to high-value whitebark pine stands;

8. Deploy fire breaks, crown thinning, and fuel reduction around/within high-value stands (e.g., seed-producing stands, *in situ* reserves) to reduce risk of destruction from wildfire;

9. Coordinate conservation action strategies with land managers to ensure that protection of whitebark pine is considered in land use planning at various scales (Land Use Framework, regional plans, site plans);

10. Review and provide direction on management of whitebark pine to provincial policy/guidelines such as operational ground rules, forest planning standards, forest genetic resource management standards, Environmental Field Reports, and the *Gene Conservation Plan for Native Trees of Alberta* (Alberta Sustainable Resource Development 2009);

11. Develop guidelines (including setbacks) for proponents requesting *Public Lands Act* dispositions in whitebark pine habitat;

12. Explore protective options such as establishment of provincial reservations or notations on sites (e.g., high value) that require protection from development or disturbance; and

13. Implement *in situ* reserves as per the *Gene Conservation Plan for Native Trees of Alberta* (Alberta Sustainable Resource Development 2009).

8.3 Conserve Genetic Resources and Deploy Rust-resistant Whitebark Pine

1. Develop comprehensive strategic breeding and deployment plan for whitebark pine;

2. Develop a seed zone susceptibility rating for mountain pine beetle and white pine blister rust and prioritize seed zones for future gene resource management work;

3. Review existing seed zones and genetic information on adaptive variation in whitebark pine to determine opportunities for flexibility in collection and deployment strategies;

4. Make bulk and single tree cone and scion collections representing a strategic sample of natural populations from Natural Subregions and seed zones for stratification of sampling;

5. Screen for population and parent tree white pine blister rust resistance through collection of scions and seed from wild putatively resistant parent trees and subsequent greenhouse and/or field tests;

6. Propagate seedlings for *ex situ* conservation for white pine blister rust screening trials based on targeted and prioritized seed zones and for establishing multi-purpose restoration plantings including plantings of putatively white pine blister rust resistant stock. Also includes seedling production for education and outreach activity;

7. Factor in the potential influence of habitat features and environmental variables on resistance into experimental design and field testing;

8. Establish, maintain and evaluate provenance/family trials for whitebark pine and assess genetic diversity across the species range in Alberta;

9. Establish a suitable site for a clone bank composed of putatively and screened white pine blister rust-resistant trees as well as other phenotypes and genotypes of interest;

10. Review the feasibility of establishing seed orchards;

11. Estimate potential loss of genetic diversity resulting from white pine blister rust;

12. Develop a comprehensive germplasm bank for whitebark pine (germplasm refers to a collection of genetic resources such as a seed collection or live trees in a nursery); and

13. Revise provincial genetic conservation strategy for whitebark pine.

8.4 Habitat and Natural Regeneration Management

1. Examine the impact of fire and industrial disturbance for regeneration and survival at the tree and stand level across an elevational and latitudinal gradient;

2. Examine the role of competition in stand dynamics and regeneration across an elevational and latitudinal gradient;

3. Characterize regeneration niche of whitebark pine by examining sites utilized by Clark's nutcracker and supporting regeneration in areas of different origin (e.g., fire, harvest, climax stands);

4. Assess use of fire and selective thinning to remove competing plant species in high-value stands;

5. Work with fire managers to develop strategies for mitigating damage from wildfire and identity opportunities to use prescribed fire as a conservation tool;

6. Explore feasibility of assisted migration in the face of climate change-induced habitat shift and, if feasible, recommend course of action;

7. Determine effects of white pine blister rust on cone and seed production, including stress crops, mast vs. non-mast years, and on nutcracker population dynamics;

8. Determine importance of alternate host species for white pine blister rust other than *Ribes*, in different habitat throughout the Alberta range of whitebark pine;

9. Assess nutcracker habitat requirements for feeding, seed caching and reproduction with mapping and modeling approaches; repeat habitat assessment every five years;

10. Monitor nutcracker populations across the range of WBP in Alberta in mast and non-mast years;

11. Work with local natural history clubs and citizen science groups to obtain information on distribution and abundance of Clark's nutcracker in Alberta;

12. Facilitate natural regeneration and supplemental planting of whitebark pine to ensure food source for nutcrackers to maintain populations for seed dispersal;

13. Examine effect of seed predation by both birds and rodents on reproductive potential;

14. Determine significance of whitebark pine seeds as a food source for Clark's nutcracker and grizzly bear diet throughout Alberta range of whitebark pine;

15. Develop study of cone development and phenology, including age of tree maturity for cone production, rates of cone and seed development, seed nutrient dynamics through growing season, and consequence of these factors on germination;

16. Document mycorrhizal associates of whitebark pine in different habitats throughout Alberta range and explore role in germination of seeds and establishment of seedlings;

17. Identify aspects of habitat alteration that interfere with regeneration; and

18. Build whitebark pine restoration into reclamation plans for commercial/industrial operations.

8.5 Information and Outreach

1. Engage private landowners and disposition holders in identification and stewardship of whitebark pine;

2. Provide outreach to recreational users through interpretive programs, public presentations, and printed material.

8.6 Research

1. Communicate research priorities to research institutions; and

2. Advocate for, sponsor, and/or implement research priorities as documented in Section 6.0.

8.7 Plan Implementation, Management and Administration

1. Maintain the Recovery Team co-chairs as the key contacts for consultation regarding activities that affect or may affect whitebark pine as well as liaison with related initiatives;

2. Conduct annual Recovery Team meetings and reporting (including evaluation/adjustment of recovery actions and priorities based on new information);

3. The Recovery Team provides overall coordination and implementation of this Recovery Strategy; and

4. Recognition of team members' contributions toward recovery goals.

8.8 Resource Acquisition

1. Approach government, non-government, and industry partners to participate in or fund whitebark pine recovery initiatives.

9.0 IMPLEMENTATION SCHEDULE AND COSTS

The following schedule (Table 3) provides a timeline and estimated minimum costs (including direct and "in-kind" – "in-kind" is used when there are costs associated but they are absorbed within the normal operating costs of government or provided by another organization or industry) for implementation of activities identified by the recovery team as being important to the conservation of whitebark pine in Alberta. The total cost over the five-year implementation period is $2,759,000 ($1,784,000 cash; $975,000 in-kind). In general, costs are relatively similar from year to year because most activities will occur in all years during the implementation period. However, the budget includes modest cost increases over the life of the Plan to account for annual inflation, a reduction in some costs over time with an accompanying increase in others particularly with active restoration over the range in Alberta. It is anticipated that a variety of agencies will participate in the funding and implementation of these activities.

Estimated costs shown are direct and essential in-kind costs to implement recovery actions. Costs associated with team members' expenses to attend recovery team meetings are not included in the table, but represent valued and necessary contributions associated with implementation of the recovery plan. Direct costs for earlier actions were largely met through existing budgets of Alberta Environment and Sustainable Resource Development (Forestry Division), Alberta Tourism, Parks and Recreation (Parks Division), and Parks Canada (Waterton Lakes National Park).

Table 3. Implementation table for whitebark pine recovery actions including cash and in-kind contributions. Abbreviations for agencies: ESRD For = Alberta Environment and Sustainable Resource Development – Forestry Division; ESRD-F&W = Alberta Environment and Sustainable Resource Development – Fish and Wildlife Division; TPR= Alberta Tourism, Parks and Recreation – Parks Division; PCA= Parks Canada Agency (Waterton Lakes National Park); CFS=Canadian Forest Service. Implementation is subject to the availability of resources, from within and from outside government.

Recovery Plan Section	Action	Lead Agency[1]	Cost (thousands per fiscal year)[2]					Total	Priority[3]
			2013/ 2014	2014/ 2015	2015/ 2016	2016/ 2017	2017/ 2018		
8.1	**Population monitoring (inventory and assessment)**								
1	Map and inventory distribution; stratify by region	ESRD-For TPR	5 IK 10	5 IK	5 IK	1 IK	1 IK	10 17 IK	Urgent
2	Re-assess established health plots every 5-6 years, analyze data and create maps	TPR ESRD-F&W ESRD-For	10 5 IK 2 IK	5 5 IK 2 IK	5 5 IK 2 IK	2 IK	20 2 IK	40 25 IK	Urgent
3	Collect data for community type classification	ESRD-For	4 IK	4 IK	4 IK	4 IK	4IK	20 IK	Urgent
4	Data for PVA	ESRD-For	Incl. in other work					0	Urgent
5	Map mountain pine beetle infestations in whitebark pine annually	ESRD-For PCA CFS	10	10	10	10	10	50 IK	Necessary
6	Establish data standards, database, and perform analyses	TPR	5 IK	5 IK	5 IK	5 IK	5 IK	25 IK	Urgent
7	Support development of predictive habitat models	ESRD-For/F&W		25	25			50	Urgent
8	Synthesize all monitoring and related data to identify stands for protection	ESRD TPR		5 IK 2 IK				7 IK	Necessary
9	Determine criteria for "high value" trees and stands	ESRD-For ESRD- F&W TPR PCA	3 IK 1 IK 1 IK 1 IK					6 IK	Urgent

Recovery Plan Section	Action	Lead Agency[1]	Cost (thousands per fiscal year)[2]					Total	Priority[3]
			2013/ 2014	2014/ 2015	2015/ 2016	2016/ 2017	2017/ 2018		
10	Establish pre- and post-treatment monitoring plots and protocols to assess impacts of fire and harvesting	ESRD-For TPR PCA	5 IK 2 IK	5 IK 13 IK 2 IK	5 IK 13 IK 2 IK	5 IK 13 IK 2 IK	5 IK 13 IK 2 IK	87 IK	Urgent
11	Non-lethal effects of white pine blister rust	ESRD		10				10	Beneficial
12	Analyze change through old survey or air photos	ESRD			15			15	Beneficial
13	Carry out pest survey and assessment	PCA PCA	20	20 2 IK	20 2 IK	20 2 IK	20 2 IK	100 8 IK	Beneficial
14	Record insect and disease problems in established Permanent Sample Plots (PSP) and Research Sample Plot (RSP)	ESRD-For	3 IK	3 IK	3 IK	3 IK	3 IK	15 IK	Beneficial
15	Engage existing initiatives to facilitate early detection of plant health problems	TPR ESRD-For	3 IK 1 IK	3 IK 1 IK	3 IK 1 IK	1 IK 1 IK	1 IK 1 IK	16 IK	Beneficial
16	Carry out seed zone review to determine flexibility for seed collections and deployment based on genetic information	ESRD-For	2 IK					2 IK	Urgent
8.2	**Protection of whitebark pine stands**								
1	Identify" high-value" WBP and stands that require protection	Recovery Team	1 IK	5 IK	5 IK	5 IK	5 IK	21 IK	Urgent
2	Remove mountain pine beetle-infested pine in/near high-value WBP stands	ESRD-For	75	75	75	75	75	375	Urgent
3	Deploy semiochemicals in high-value whitebark pine stands to deter mountain pine beetle during an infestation	ESRD-For PCA	20 3	20 3	20 3	20 3	20 3	115	Urgent
4	Communicate to fire managers regarding location and protection of high-value stands	ESRD-For TPR	1 IK 1 IK	1 IK 1 IK	1 IK 1 IK	1 IK 1 IK	1 IK 1 IK	10 IK	Urgent
5	Exclude/protect high-value WBP in burn units	ESRD-For TPR PCA	 1 IK 1	4 IK 1	4 IK 1	4 IK 1	4 IK 1	5 17 IK	Urgent
6	Assess wildfire risk in high value WBP stands	ESRD-For TPR		3 IK 3 IK	3 IK 3 IK	3 IK 3 IK		18 IK	Necessary

Recovery Plan Section	Action	Lead Agency[1]	Cost (thousands per fiscal year)[2]					Total	Priority[3]
			2013/ 2014	2014/ 2015	2015/ 2016	2016/ 2017	2017/ 2018		
7	Work with fire and forest managers to identify and manage lodgepole pine stands adjacent to WBP stands that are at high risk of mountain pine beetle infestation	ESRD-For		1 IK		1 IK		2 IK	Necessary
8	Protect high-value WBP stands from wildfire	ESRD-For TPR PCA	1 IK 1 IK 1 IK	4 IK 1 IK 1 IK	4 IK 1 IK 1 IK	4 IK 1 IK 1 IK	4 IK 1 IK 1 IK	27 IK	Beneficial
9	Coordinate conservation strategies with land managers in land use planning.	ESRD	2 IK	2 IK	2 IK	2 IK	2 IK	10 IK	Necessary
10	Review and comment on provincial policy/guidelines	ESRD-For TPR	3 IK 3 IK	1 IK 1 IK	1 IK 1 IK			10 IK	Necessary
11	Develop guidelines (including setbacks) for *Public Lands Act* dispositions.	ESRD-F&W ESRD-For	2 IK 2 IK	2 IK 2 IK	2 IK 2 IK	2 IK 2 IK	2 IK	18 IK	Necessary
12	Explore options for long-term protection of stands on crown land through provincial reservation system	ESRD-For	1 IK	1 IK	1 IK	1 IK	1 IK	5 IK	Necessary
13	Implement *in situ* reserves as per the provincial conservation plan.	ESRD-For	3 IK	15 IK	15 IK	15 IK	15 IK	63 IK	Urgent
8.3	**Conserve genetic resources, screen, propagate, breed and deploy whitebark pine**								
1	Develop strategic breeding and deployment plan	ESRD-For		10				10	Urgent
2	Develop a susceptibility rating of priority seed zones for mountain pine beetle and white pine blister rust	ESRD-For		5 IK	5 IK			10 IK	Necessary
3	Role of seed zones and adaptive variation in collection and deployment strategies	ESRD- For		3 IK	3 IK			6 IK	Necessary
4	Strategically make bulk and single tree cone and scion collections	ESRD-For PC	60 2 IK	60 2 IK	60 2 IK	80 2 IK	80 2 IK	340 10 IK	Urgent
5	Screen for rust resistance from seed and	ESRD-For	30 IK	30 IK	30 IK	30 IK	30 IK	150 IK	Urgent

Recovery Plan Section	Action	Lead Agency[1]	Cost (thousands per fiscal year)[2]					Total	Priority[3]
			2013/ 2014	2014/ 2015	2015/ 2016	2016/ 2017	2017/ 2018		
	scion collection from putatively resistant trees								
6	Propagate seedlings for *ex situ* conservation and restoration plantings	ESRD-For	15 IK	15 IK	15 IK	15 IK	15 IK	75 IK	Urgent
7	Examine influence of environmental variables on rust resistance	ESRD-For			20	20	20	60	Beneficial
8	Establish provenance/family trials and assess genetic diversity	ESRD-For	2 IK	40	40	25		105 2 IK	Necessary
9	Establish a field clone bank for various genotypes and phenotypes	ESRD-For		40	40	40		120	Necessary
10	Review the feasibility of establishing seed orchards	ESRD-For		3 IK	3 IK			6 IK	Beneficial
11	Estimate potential loss of genetic diversity due to white pine blister rust	ESRD-For			10 IK	10 IK	10 IK	30 IK	Necessary
12	Develop a comprehensive germplasm bank	ESRD-For	5 IK	5 IK	5 IK	5 IK	5 IK	25 IK	Urgent
13	Revise provincial genetic conservation strategy	ESRD-For TPR	1 IK	1 IK 1IK				3 IK	Beneficial
8.4	**Habitat and natural regeneration management**								
1	Examine impact of disturbance for regeneration and survival	ESRD	5 IK	10IK	10IK	3 IK	3 IK	31 IK	Necessary
2	Examine role of competition in stand dynamics	ESRD-For		15 IK	5 IK	3 IK		23 IK	Necessary
3	Characterize regeneration niche	TPR	10 IK	3 IK	3 IK			16 IK	Urgent
4	Assess competition removal methods	ESRD-For TPR	5 IK	3 IK	1IK	1 IK	1 IK	11 IK	Necessary
5	Develop strategies for working with wildfire and prescribed fire	ESRD-For TPR PCA	2 IK 2 IK 2 IK	2 IK 2 IK 2 IK	2 IK 2 IK 2 IK			27 IK	Necessary
6	Explore feasibility of assisted migration	TPR			2 IK	2 IK		4 IK	Beneficial
7	Determine effects of white pine blister rust	ESRD-For		10	10			20	Beneficial

Recovery Plan Section	Action	Lead Agency[1]	Cost (thousands per fiscal year)[2]					Total	Priority[3]
			2013/ 2014	2014/ 2015	2015/ 2016	2016/ 2017	2017/ 2018		
	on cone and seed production								
8	Determine importance of alternate host species for white pine blister rust	ESRD				15		15	Beneficial
9	Assess nutcracker habitat requirements	ESRD			15	10	10	30	Beneficial
10	Monitor nutcracker populations in mast and non-mast years	TPR PC	1 IK 2	2 IK 2	2 IK 2	1 IK 2	1 IK 2	10 7 IK	Necessary
11	Gather information on distribution and abundance of nutcrackers	TPR	1 IK	2 IK	2 IK	1 IK	1 IK	7 IK	Necessary
12	Ensure regeneration as future food source to keep nutcrackers on landscape	PC	1 IK	1 IK	1 IK	1 IK	1 IK	5 IK	Necessary
13	Examine effect of seed predation on reproductive potential	ESRD			20	20	20	60	Beneficial
14	Determine significance of seeds as food source for nutcracker and grizzly bear	ESRD/TPR/ PCA		10	10	10		30	Beneficial
15	Develop study of cone development and phenology	ESRD-For		5 IK	20	20		40 5 IK	Necessary
16	Document mycorrhizal associates and examine their ecology	ESRD		10	10	10		30	Necessary
17	Identify aspects of habitat alteration that interfere with regeneration	ESRD-For		1IK	1 IK			2 IK	Necessary
18	Build restoration into reclamation plans for commercial operations.	PCA ESRD	2 IK	1 IK 5 IK				8 IK	Beneficial
8.5	**Information and outreach**								
1	Engage private landowners and disposition holders	ESRD	2 IK	2 IK	1 IK	1 IK	1 IK	7 IK	Necessary
2	Provide outreach to recreational users	ESRD/TPR/ PCA	3 IK	7 IK	3 IK	3 IK	3 IK	19 IK	Necessary
8.6	**Research**								
1	Communicate research priorities to research institutions	TPR PC	5 IK 3 IK	1 IK 2 IK	1 IK 2 IK	1 IK 2 IK	1 IK 2 IK	20 IK	Necessary

Recovery Plan Section	Action	Lead Agency[1]	Cost (thousands per fiscal year)[2]					Total	Priority[3]
			2013/ 2014	2014/ 2015	2015/ 2016	2016/ 2017	2017/ 2018		
2	Advocate for and/or sponsor research priorities as documented in (section 6.0)	TPR PC ESRD	1 IK 1 IK 1 IK	1 IK 1 IK 1 IK	1 IK 1 IK 1 IK	1 IK 1 IK 1 IK	1 IK 1 IK 1 IK	15 IK	Beneficial
8.7	**Plan implementation, management and administration**								
1	Maintain the recovery team chairs as the key contact for consultation and liaison	ESRD	2 IK	2 IK	2 IK	2 IK	2 IK	10 IK	Urgent
2	Conduct annual recovery team meetings and reporting	ESRD	0.5	0.5	0.5	0.5	0.5	2.5	Urgent
3	Overall coordination and implementation	ESRD	15	16	17	18	19	85	Necessary
4	Recognition of team members' contributions toward recovery goals	ESRD-F&W	0.5					0.5	Beneficial
8.8	**Resource acquisition**								
1	Funding securement	ESRD	1 IK	1 IK	1 IK	1 IK	1 IK	5 IK	Urgent
	TOTAL		277 177 IK	367.5 236 IK	438.5 222 IK	399.5 178 IK	301.5 162 IK	1784 945 IK	

[1] Lead agencies are identified for those groups that will be taking the management actions. The lead agency will engage other agencies according to all current policies, agreements, MOUs, and availabilities of expertise. Agencies and proposed costs in no particular order.
[2] IK – In kind contribution by identified agency(s)
[3] Prioritization: Urgent = high priority for immediate species conservation, initiate as soon as possible; Necessary = medium priority for long term species conservation; Beneficial = lower priority, primarily directed at potential future activities

10.0 SOCIO-ECONOMIC CONSIDERATIONS

The principles identified in Section 7.2 of this plan will guide recovery actions for whitebark pine. During implementing this recovery plan, social and economic impacts will be considered to develop a cooperative approach among stakeholders. Recovery efforts will likely have nominal economic effect on industries working in whitebark pine habitat, most notably forestry and energy. The effect is small because so far, only a relatively small part of whitebark pine habitat overlaps with areas suitable for industrial development (although this could change in the future). Recreationalists will also be affected but any economic costs are potentially less than what is gained from maintaining whitebark pine on the landscape. In that way, whitebark pine contributes significantly to natural capital in its role as a keystone and foundation species (Tomback *et al*. 2011).

Protection of sites for high-value stands could increase the costs of industrial or recreational development. Costs to industry may occur at the planning level through road re-alignment or changing block or lease boundaries. Incurrence of some cost to industry and recreational developers would also be expected as they work to reduce their impact on regeneration or reduce incidental death of whitebark pine trees; however, increased recognition and support is anticipated for those operators that demonstrate responsible conservation practices by accepting constraints that benefit the needs of whitebark pine.

Removal of lodgepole pine trees to protect whitebark pine stands from MBP risk, or to reduce competition, could affect the timber resources in localized areas. However, monitoring new diseases/pests as part of whitebark pine recovery could also benefit forestry and natural capital.

Reducing wildfire or altering prescribed fire plans near high-value whitebark pine stands could interfere with other benefits that occur in the wake of fire, but could potentially benefit other species that prefer older growth. Removal of other plant species to reduce competition could negatively affect other sensitive species if they are removed.

Little is known about traditional use of whitebark pine by First Nations in Alberta; however, the species was, and in many areas still is, used in several other areas of its range as a food source (e.g., Turner *et al*. 1980; Turner 1997; Lee 2003; and other sources reviewed by Keane *et al*. 2012). For example, in the interior region of B.C., the Thompson and Ts'ilhqot'in people were known to consume the seeds (Turner 1997). In autumn, they collected cones and opened the cone scales by drying them. They extracted the seeds to eat fresh or preserved them for winter use by first roasting, then crushing them and mixing them with dried berries, or by pounding the roasted seeds into flour.

Other parts of whitebark pine trees were also used by First Nations (reviewed by Keane *et al*. 2012). For example, the inner bark 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 (Antos *et al*. 1996).

Aside from specific conservation benefits of the species itself, as well as both the conservation benefits to Clark's nutcrackers and the benefits to biodiversity derived when enough whitebark pine persist on the landscape to maintain populations of Clark's nutcrackers, recovery of whitebark pine will benefit biodiversity in Alberta and support the ecosystem services that this species provides.

Other activities such as inventory, monitoring and research aimed at whitebark pine and Clark's nutcrackers, collecting cones, breeding/screening/planting, and deploying semiochemicals, would have minimal effect on other interests or other species beyond the cost of these activities.

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