Fish & Wildlife Division

SPECIES AT RISK

Status of the Whitebark Pine (*Pinus albicaulis*) in Alberta

Alberta Wildlife Status Report No. 63

Alberta Conservation Association

Alberta

Status of the Whitebark Pine (*Pinus albicaulis*) in Alberta

Prepared for:
Alberta Sustainable Resource Development (SRD)
Alberta Conservation Association (ACA)

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PREFACE

Every five years, the Fish and Wildlife Division of Alberta Sustainable Resource Development reviews the general status of wildlife species in Alberta. These overviews, which have been conducted in 1991 (*The Status of Alberta Wildlife*), 1996 (*The Status of Alberta Wildlife*), 2000 (*The General Status of Alberta Wild Species 2000*), and 2005 (*The General Status of Alberta Wild Species 2005*) assign individual species "ranks" that reflect the perceived level of risk to populations that occur in the province. Such designations are determined from extensive consultations with professional and amateur biologists, and from a variety of readily available sources of population data. A key objective of these reviews is to identify species that may be considered for more detailed status determinations.

The Alberta Wildlife Status Report Series is an extension of the general status exercise, and provides comprehensive current summaries of the biological status of selected wildlife species in Alberta. Priority is given to species that are *At Risk* or *May Be At Risk* in the province, that are of uncertain status (*Undetermined*), or that are considered to be at risk at a national level by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Reports in this series are published and distributed by the Alberta Conservation Association and the Fish and Wildlife Division of Alberta Sustainable Resource Development. They are intended to provide detailed and up-to-date information that will be useful to resource professionals for managing populations of species and their habitats in the province. The reports are also designed to provide current information that will assist Alberta's Endangered Species Conservation Committee in identifying species that may be formally designated as *Endangered* or *Threatened* under Alberta's *Wildlife Act*. To achieve these goals, the reports have been authored and/or reviewed by individuals with unique local expertise in the biology and management of each species.

EXECUTIVE SUMMARY

Whitebark pine (*Pinus albicaulis*) is found in high elevation forests in the mountainous regions of western North America. This hardy tree is a "keystone" species, as its seeds provide an important food source for a number of animals including squirrels, bears and, in particular, Clark's nutcracker (*Nucifraga columbiana*). In Alberta, the species is found in isolated populations in the Rocky Mountains from Willmore Wilderness Park south to the Canada-U.S. border. However, exact numbers of individuals are difficult to estimate because of limited stand inventory throughout its provincial distribution.

There are four main human-caused threats to whitebark pine throughout its range: 1) white pine blister rust (*Cronartium ribicola*), an introduced fungus species; 2) increased presence of mountain pine beetle (*Dendroctonus ponderosae*); 3) prolonged widespread fire suppression; and 4) rapid global climate change. In Alberta, the greatest threat is white pine blister rust. The vast majority of whitebark pine stands in Alberta are infected with this introduced fungus, which has already caused significant mortality in many stands, with the greatest effects evident in southern Alberta.

A number of initiatives is needed for effective conservation and restoration of Alberta whitebark pine. Such initiatives include a detailed inventory of the species (the Alberta Vegetation Inventory poorly documents the occurrence and abundance of whitebark pine), a long-term rust-resistant tree identification and seed collection program, and liaison with land managers working in whitebark pine forests in order to identify best operating practices to ensure continued recruitment opportunities for the species.

ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

TABLE OF CONTENTS cont.

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Whitebark pine (*Pinus albicaulis*) is found in high elevation forests in the mountainous regions of western North America (Arno and Hoff 1989). The majority of the Canadian populations are associated with mountain ranges in the southern half of British Columbia. In Alberta, the species is found most frequently on steep, southwestern aspects above 1500 m in the Rocky Mountains. Whitebark pine is ranked S2/G4* by the Alberta Natural Heritage Information Centre (Gould 2006). This species has not been assessed by COSEWIC (Committee on the Status of Endangered Wildlife in Canada).

Whitebark pine is a hardy species that is an important part of high elevation environments where it is found. This tree is a "keystone" species (Lanner 1996), because its seeds provide an important food source for a number of animals, including red squirrels, bears and, in particular, Clark's nutcracker, *Nucifraga columbiana* (Kendall 1983, Mattson et al. 2001, Tomback and Kendall 2001). Whitebark pine also plays an important role in watershed protection by aiding soil stability. The species facilitates a more rapid return to forested landscapes following disturbances on southern exposures, where harsh conditions may otherwise limit seed germination and establishment (Arno and Hoff 1989, Callaway 1998).

This report summarizes current and historical information about whitebark pine in Alberta. This information will be used to assess the status of the species in Alberta and to guide development of prospective management and conservation strategies.

* See Appendix 1 for definitions of selected status designations.

HABITAT

Throughout its range in western Alberta, whitebark pine is restricted to high elevation environments. It generally occurs on drier southwestern aspects, from timberline down to closed subalpine forest, where it is eventually replaced by more competitive tree species (Weaver 2001). This pine is considered to be relatively shade intolerant, and is therefore a seral species in mixed subalpine stands. Regeneration is most often associated with early seral environments created by avalanche, glacial retreat, or most importantly, fire. However, at higher elevations where fuels are less continuous, whitebark pine forms stable communities and may persist for over a millennium (Arno and Hoff 1989, Perkins and Swetnam 1996).

Whitebark pine is associated with a number of forest community types. At higher elevations in the northwestern part of the species' distribution, whitebark pine is frequently associated with Engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*), and mountain hemlock (*Tsuga mertensiana*). At lower elevations, lodgepole pine (*Pinus contorta*) and Douglas-fir (*Pseudotsuga menziesii*) occur with whitebark pine (Ogilvie 1990, Campbell 1998). In southern Alberta, whitebark pine continues its association with Engelmann spruce and subalpine fir in higher areas, but may also be found adjacent to alpine larch (*Larix lyallii*). Lower elevation habitat in southern Alberta is also occupied by lodgepole pine and occasionally Douglas-fir, or limber pine (*P. flexilis*) (Corns and Achuff 1982, Wilson 2001). At the Canada-U.S. border, and to the south, these species associations slowly give way to a variety of other pine and fir species, including western white pine (*P. monticola*), foxtail pine (*P. balfouriana*), Great Basin bristlecone pine (*P. longaeva*), Washoe pine (*P. washoensis*), Jeffrey pine (*P. jeffreyi*), white fir (*A. concolor*), and red fir (*A. magnifica*) (Arno and Hoff 1989, Howard 2002).

Franklin and Dyrness (1988) describe whitebark pine as existing chiefly on podzolic soils, but it is also found on regosolic and lithosolic soils in the Pacific Northwest. The pH of these soil environments is typically acidic, ranging from 4.5 to 5.9. In Alberta, the soils that support whitebark pine are chiefly Orthic Eutric Brunisols, Orthic Regosols, and Dystric Brunisols. These soils are also typically acidic (Walker et al. 1982a). The parent material over the range of whitebark pine is varied, including glacial till, colluvium, and eolian material, derived from sedimentary, igneous, and metamorphic rock (Walker et al. 1982b, Franklin and Dyrness 1988).

Whitebark pine populations occur across a broad range of environmental conditions. In the higher continental areas, minimum winter temperatures can reach below -40°C, whereas summer temperatures can climb up to 30°C (Arno and Hoff 1989). Although a protective snow pack covers seedlings in most areas during winter, Weaver (2001) notes that seedlings may experience lethal summer soil temperatures nearing 60°C at the soil surface. For mature trees, frost during the spring bud break or before new growth has hardened off in the fall may cause significant damage. Optimal photosynthesis in young seedlings occurs near 20°C, and optimal root growth has been observed at soil temperatures of 30°C (Jacobs and Weaver 1990).

Precipitation in whitebark environments can vary considerably. Arno and Hoff (1989) note that mean annual precipitation is between 600 mm and 1800 mm, with most of this falling as snow. However, Weaver (2001) suggests that even in seemingly dry sites, whitebark pine likely experiences little drought because of the high water-holding capacity of the soil. The pine is unlikely to survive in situations where the water potential drops below -0.5 Mpa, such as warm, lower elevation grasslands (Weaver 2001). Winter desiccation and damage to exposed aboveground tissues by wind-blown snow and ice particles also limit the species growth in timberline areas (Arno and Hammerly 1984).

Human influences that reduce the suitability of whitebark pine habitat, such as fire suppression and climate change, have increased significantly over the last 100 years (Tomback et al. 2001, Weaver 2001, Wilson and Stuart-Smith 2002). These influences will be addressed in detail in the section on limiting factors below.

CONSERVATION BIOLOGY

Whitebark pine is a small- to medium-sized tree. In Canada, mature specimens typically range in height between 5 m and 20 m, and may reach over a metre in diameter at the base (Hosie 1979, Douglas et al. 1998). In many cases, genetically distinct individuals that have arisen from the same cache of seeds give the appearance of multiple stems joined at or below the soil (Furnier et al. 1987, Rogers et al. 1999). The bark on younger individuals is smooth light grey to white, thus influencing the choice of common name.

The needles are in bundles of five and vary in length between about 5 cm and 10 cm, although needles have been recorded up to 18 cm long (Howard 2002). The female cones are compact, remain closed at maturity, and vary in length between about 4 cm and 8 cm. They are at the outer ends of branches, generally towards the top part of the tree. Male cones are small (approximately 1 cm long) and are on new growth throughout the canopy (McCaughey and Tomback 2001).

Whitebark pine is a long-lived species. The tree often attains an age of over 500 years in more open undisturbed sites where it would be expected to live the longest (Arno and Hoff 1989) and sometimes reaches more than 1000 years (Perkins and Swetnam 1996). In Alberta, the oldest recorded individual is approximately 1100 years old (Luckman and Youngblut 1999).

The species is also late to reach sexual maturity, generally does not produce cones until 25–30 years of age, and has no sizable cone crops until 60–80 years of age (Arno and Hoff 1989, McCaughey and Tomback 2001, B. Wilson, unpubl. data). In spite of this delay, sexual reproduction is overwhelmingly the primary means of reproduction. Arno and Hoff (1989) note that the little vegetative reproduction that does occur appears to be through the occasional rooting of longer, lower branches weighed down by snow.

The reproductive cycle is similar to other pines and follows a two-year path from cone initiation to seed maturity (McCaughey 1994). Female cones produce about 75 seeds on average. The seeds are relatively large (7.6 mm) and have a mean weight of about 300 mg (Arno and Hoff 1989, McCaughey and Tomback 2001, B. Wilson, unpubl. data). Whitebark pine produces mast crops of seeds every three to five years with intervening years having very low or no seed production (Morgan and Bunting 1992).

The nutrient-rich seeds are wingless and, since the cone does not open (indehiscent), they remain in the cone after maturity. These cones are a distinctive feature of the stone pine subsection of the genus *Pinus*. All of the stone pines on other continents also show evidence of a mutualistic relationship with nutcracker species (Lanner 1996). Whitebark pine is almost entirely dependent on Clark's nutcracker for successful dispersal and reproduction. Clark's nutcracker is thought to have co-evolved with whitebark pine and serves as the pine's only effective seed disperser (Tomback 1982, Lanner 1980). Nutcrackers feed almost exclusively on whitebark pine seeds when they are available and store the seeds for use throughout the year (Tomback 1978). Clark's nutcrackers have a sublingual pouch that can hold up to 150 whitebark pine seeds, an adaptation that is unique among birds (Bock et al. 1973). With a full pouch, nutcrackers fly off to a suitable site where clusters of up to 15 seeds are cached 2 cm to 3 cm below the soil surface (Tomback 1982). The birds have been observed travelling anywhere from several hundred metres to over 10 km to cache seeds (Tomback 2001). Preferred caching sites tend to be in recently burned areas on southern aspects.

The seeds of whitebark pine are not only important to Clark's nutcracker, but also to other animals such as red squirrels (*Tamiasciurus hudsonicus*) and bears (Arno and Hoff 1989). Red squirrels, in order to prolong seed storage time, hoard whole cones in underground middens (Mattson et al. 2001). Both black bear (*Ursus americanus*) and grizzly bear (*U. arctos*) have also been seen climbing into trees to remove cones, but more often they will simply raid the already concentrated source in squirrel middens (Kendall 1983). However, none of these species is thought to help to disperse the seeds significantly (Lanner 1996).

DISTRIBUTION

Fossil evidence indicates that whitebark pine has been a member of North American subalpine ecosystems for at least 100 000 years (Baker 1990). During the period 10 000 to 15 000 years ago, the species was more widespread in the cooler, post-glaciation environmental conditions. During the warm, dry Hypsithermal period (8350 to 3000 BP), whitebark retreated to higher elevations with reduced abundance (Reasoner and Hickman 1989, McCaughey and Schmidt 2001). A cooling trend since that time has resulted in the present distribution and abundance of whitebark pine in Canada (Figure 1).

1. Alberta - In the Rockies, the northern limit of whitebark pine is approximately 150 km north of Jasper in Willmore Wilderness Park on the B.C.-Alberta border at about 54^{o}N (Ogilvie 1990). Within Alberta, it occurs in the Rocky Mountain Natural Region (Alberta Natural Heritage Information Centre 2006b),

Figure 1. The continental distribution of whitebark pine. Adapted from U.S. Geological Survey (1999).

but the actual locations of stands that contain whitebark pine are poorly mapped. The general pattern is that the species occurs in greater density following the continental divide south through Jasper and Banff national parks, and the provincial lands south to the Canada-U.S. border on the southern edge of Waterton Lakes National Park (WLNP) (Figure 2).

Because whitebark pine is a high elevation species, the stands occur on mountainsides and therefore experience varying degrees of isolation, depending on the location of suitable habitat. The stands located near the continental divide tend to be closer together, given the narrower headwater valley systems. More isolated stands occur on the eastern slopes of the Rockies, where suitable conditions exist. Figure 2 also shows apparent isolation between the southernmost stands in the WLNP region and those further north at the southern end of Peter Lougheed Provincial Park. It should be noted that there is only a narrow band of habitat in a suitable elevation range on the Alberta side of the provincial border connecting these regions. However, more high elevation habitat in the British Columbian Rockies provides additional connectivity. Stuart-Smith (1998) notes that genetic diversity was higher than expected for the assumption of low gene flow between "isolated" whitebark pine populations in the Canadian Rockies. Stuart-Smith goes on to suggest that this may reflect enough gene flow from bird-mediated dispersal and wind pollination to alleviate the effects of isolation within stands that he sampled between WLNP and the Jasper area. Another consideration is that problems with inventory accuracy or availability may have contributed to paucity of whitebark records in the southern third of the province, and areas north of Jasper in the Willmore Wilderness Park region.

In eastern regions, there has been some confusion between whitebark and limber pine, a species with a similar biology and habitat requirements (Alberta Sustainable Resource Development and Alberta Conservation Association 2007). However, with a few exceptions, whitebark pine will generally be found above 1500 m and limber pine below this elevation. The majority of whitebark stands in Alberta are located on steep terrain (between 40% and 70% slopes) and on warmer south-southeast to west-northwest aspects (B. Wilson, unpubl. data). The provincial extent of occurrence for whitebark pine in Alberta accounts for less than 10% of the species' continental distribution (Table 1).

The area of occupancy for whitebark pine in Alberta can be estimated at 1099 km^2 (based on the area of the polygons and point data shown in Figure 2), or somewhat higher at 7148 km^2 (derived from the polygon area occupied on a 2 km x 2 km grid overlay). However, there can be little confidence associated with these area of occupancy estimates; the inventory problems noted above may result in area of occupancy being underestimated.

Table 1. Extent of occurrence for whitebark pine (derived from a minimum convex hull polygon of the species' distribution in Alberta). Disjunctions in the overall distribution have not been excluded.

Jurisdiction	Area (km^2)
Alberta	29 786
British Columbia	217 369
U.S.	146 396
Total	393 551

2. Other areas - The continental distribution of whitebark pine occurs in two distinct geographical distributions. The first extends through the Coast and Cascade Mountains in British Columbia, Washington, and Oregon, to the Sierra Nevada of central California (Figure 1). The second follows the major ranges of the Rockies from approximately 54^{o}N in British Columbia, to 41^{o}N in the Wind River Range in western Wyoming (Ogilvie 1990). The majority of the extent of occurrence for whitebark pine is within Canada, and most of the Canadian distribution occurs within British Columbia (Table 1).

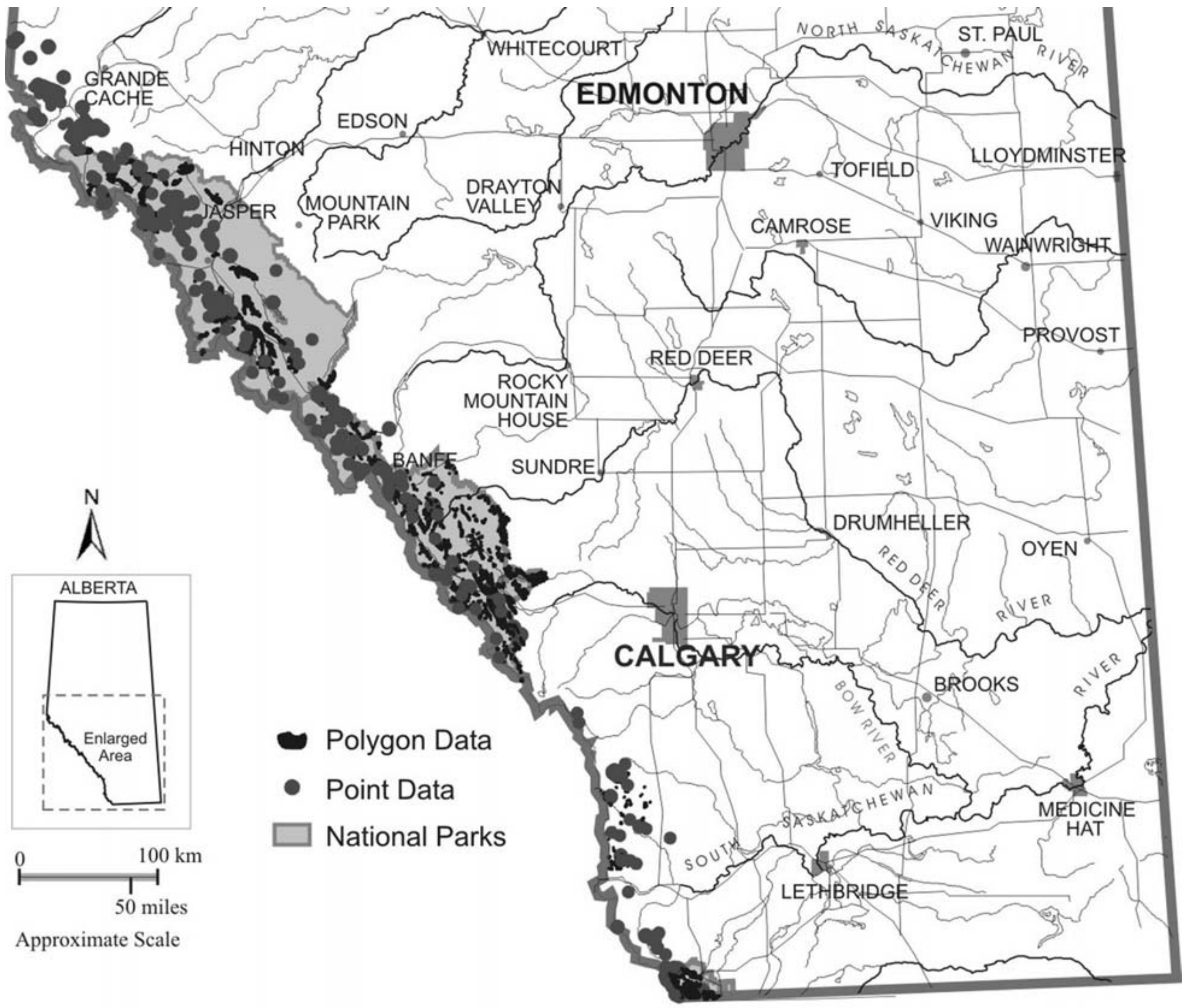

Figure 2. Estimate of the distribution of whitebark pine in Alberta. Polygon data are derived from Corns and Achuff (1982) and the Alberta Vegetation Inventory. Point data are from Smith et al. (in press), Alberta Natural Heritage Information Centre, Alberta Tourism, Parks, Recreation and Culture, and ongoing Alberta Sustainable Resource Development studies, including data from the Ecological Site Inventory System.

LIMITING FACTORS

Most early losses to whitebark pine are caused by pre-dispersal seed predation. Seeds are harvested by fly larvae, rodents, birds, and bears (Kendall 1983, Arno and Hoff 1989, Tomback 2001). The seeds that are transported to caches may succumb to further predation by returning nutcrackers or foraging rodents. Fungal infection may also be an important source of seed mortality. Hoff and Hagle (1990) describe several fungal species that have been observed in whitebark pine seeds and seedlings in nurseries.

At lower elevations, young seedlings often occur in association with partial cover of surrounding vegetation or other nearby objects, such as woody debris and rocks (McCaughey and Tomback 2001). It is likely that these features, and the presence of multiple seedling stems arising from one cache site, moderate the temperature and moisture environment during the early growth phase and enhance seedling survival. Browsing and fungal infection may still lead to considerable mortality in the early growth stage. As a stand matures, the main sources of whitebark mortality shift to competition with other plants, periodic mountain pine beetle (*Dendroctonus ponderosae*) attack, limber pine dwarf mistletoe (*Arceuthobium cyanocarpum*) attack (Hoff and Hagle 1990, Bartos and Gibson 1990, Perkins 2001), and fire disturbance associated with the buildup of fuels.

At upper elevations, those pressures associated with continuous forest cover are reduced. The open structure of the higher elevation timberline community produces discontinuous fuels for the propagation of stand-replacing fire (Agee 1993), and coupled with the harsh climatic conditions, likely limits the influence of forest pest attack (Logan and Powell 2001). The survival of maturing whitebark pine individuals in these conditions is reliant on the species' ability to resist the abiotic environmental stress associated with timberline environments.

The factors affecting the survival of whitebark pine have changed significantly over the last 100 years as a result of human influences. There are four main anthropogenic threats to whitebark pine throughout its range: 1) white pine blister rust (*Cronartium ribicola*), an introduced species; 2) increased presence of mountain pine beetle (*Dendroctonus ponderosae)*, 3) prolonged widespread fire suppression; and 4) rapid global climate change (Tomback et al. 2001, Weaver 2001, Wilson and Stuart-Smith 2002).

1. White pine blister rust - The continued spread of the blister rust and the ensuing mortality of whitebark pine is likely the largest problem threatening this species in Alberta. Although white pine blister rust is thought to have originated in Siberia, the rust species was introduced accidentally into North America from Europe at the turn of the 20th century (Peterson and Jewel 1968, Littlefield 1981, McDonald and Hoff 2001). Since that time, blister rust has spread throughout much of the distribution of the soft pines of western North America (Liebhold et al. 1995). Whitebark pine has been affected badly; throughout the species' range there are few stands that show no infection (Stuart-Smith 1998, Campbell and Antos 2000, Zeglen 2002, Ernst 2006, Smith et al. in press), and many areas where there is greater than 90% infection and over 50% mortality from blister rust (Kendall and Keane 2001).

The extent of blister rust infection not only depends on the distribution of whitebark pine, but also on shrubs of the genus *Ribes* (currant/gooseberry) and potentially on forbs of the genera *Pedicularis* (lousewort) and *Castilleja* (paintbrush), which act as alternate hosts (McDonald et al. 2006). The life cycle of the blister rust has five stages that alternate between two hosts, white pine species and the above-mentioned alternate hosts (Zillar 1974). There are a number of excellent reviews detailing this complex life cycle (e.g., McDonald and Hoff 2001). The part of the life cycle that negatively affects the pine occurs following infection of the pine needles with the wind-borne basidiospores from the alternate host plant, usually near the end of summer. After the initial infection of pine needles, hyphae grow down the vascular bundle and enter the phloem in the branch or stem of the tree. As the rust spreads through the phloem, the nutrient supply can be cut off to branches and portions of the upper stem.

Two to four years following infection, cankers form and rupture the bark surface. Although a canker may become large enough to girdle the affected stem, infection may not be the direct cause of death. The concentrations of nutrients in cankers attract rodents that chew the canker, thus removing vascular tissue and, in many cases, girdling the stem (Lanner 1996). These losses of vascular tissue, as well as invasion by secondary pathogens into the wound, are the main cause of mortality. Brown or red-brown dead needles that droop to one side of the branch are visible symptoms of branch death from blister rust infection. An important consideration here is the loss of reproductive potential created by the early death of the distal portion of a mature tree's canopy. Because the female cones are borne on the most recent two years of branch growth, many infected mature trees become ineffective at producing seeds long before they are actually dead.

Although whitebark pine has shown high susceptibility to blister rust infection compared to other North American white pine species (Bedwell and Childs 1943), a low level of apparent resistance to blister rust has been observed (Hoff et al. 2001). Mature individuals surviving (with no or few cankers) in stands that have very high levels of infection and mortality have been found in Alberta (Smith et al. in press). Several studies note that proportionately more seedlings grown from seeds collected from those apparently disease-free (phenotypically resistant) individuals remain uninfected after artificial inoculation with blister rust spores, compared to seedlings grown from similar trees from lightly infected stands (Hoff et al. 2001, Schwandt 2006). This provides some hope for restoration projects discussed in the Synthesis section below.

2. Mountain pine beetle **-** Until recently, Canadian whitebark pine populations were not considered to be under great threat from mountain pine beetle (Stuart-Smith 1998, Campbell and Antos 2000, Zeglen 2002). However, a very large increase in beetle activity in British Columbia in the last few years (CFS 2005), and recent attacks in Willmore Wilderness Park and the Bow Valley (Alberta Sustainable Resource Development 2007a), may now put much of the Alberta whitebark population in peril. Kendall and Keane (2001) note that trees weakened by blister rust infection are more susceptible to beetle infestation (also see Kegley 2006). Therefore, the high levels of blister rust infection found in many Alberta whitebark stands (Smith et al. in press) may exacerbate this problem. Wong and Daniels (2006) suggest that in WLNP, mountain pine beetle has played a potentially important role in population dynamics during the 1980s, where 30% – 40% of the mature whitebark pine canopy may have been removed.

3. Fire suppression **-** Fire suppression has been reported as a negative effect in whitebark forests (e.g., Arno 1986, Keane 2000). Fire suppression affects whitebark pine populations in several ways. At lower elevations, a reduction in early seral habitat, where there would have been greater availability of light and nutrients for tree growth, means that fewer seeds are cached, germinate, or develop into sexually mature individuals. More shade-tolerant species, such as subalpine fir and Engelmann spruce, fill in stands (in-growth) and out-compete mature whitebark pine trees (Arno and Hoff 1989, Arno 2001).

In the typically more open, upper subalpine whitebark stands, forest in-growth also creates the risk of changing the historical fire regime.

Stands that were maintained by mixed or lower intensity fire behaviour in the past are more likely to be removed by higher intensity fires supported by an increase in fuel loadings (Agee 1990). This means that stable, late-succession stands could be converted to early seral habitat, removing older veteran seed-producing adults, and shifting the pattern of regeneration to that of the lower subalpine forest described above, where whitebark is an earlier seral component.

Prolonged fire suppression may also increase the amount of forest susceptible to mountain pine beetle and dwarf mistletoe. The reduction in the heterogeneity of stand ages and tree bole size may increase the occurrence of these pathogens (Kendall and Keane 2001).

4. Climate change **-** Climate change may also severely impact the amount of habitat available for whitebark pine. In some regions of the Rockies, warmer summer temperatures from increased atmospheric CO_2 are predicted to allow vegetation from lower elevations to advance upslope more rapidly (Hall and Fagre 2003). This will likely enhance forest in-growth in the upper subalpine and at timberline (Wilson 2001, Körner 2003), creating a more competitive environment where smaller whitebark pine may experience considerable stress. It should be remembered that little suitable habitat lies above the present alpine timberlines and that in the long term, the potential exists for high elevation plant species, such as whitebark pine, to be lost from these habitats (Grabherr et al. 1994). Warmer temperatures could also lead to an increase in mountain pine beetle activity in high elevation stands. Killing temperatures close to –40°C for only a few hours are required to naturally control beetle activity (Amman et al. 1997, Régnière et al. 2003). Warmer temperatures also permit the beetle to complete its life cycle in one year and make summer dispersal flights more dependably. With a predicted increase of 1.4°C – 5.8°C between 1990 and 2100 (IPCC 2001, Koteen 2002), beetle infestations may go unchecked by temperature over much of whitebark pine's range.

POPULATION SIZE AND TRENDS

1. Population estimate **-** Estimating the population size of mature whitebark pine trees is problematic, given its relatively wide-ranging distribution, variable densities at different locations, patchy quantitative inventory data, and only an indirect means of estimating maturity (i.e., stem diameter at breast height [DBH]). However, it is possible to make some local assessments by looking at the average values for the distribution of stem sizes and estimating the proportion of mature trees and their average density.

A recent survey (Smith et al. in press) of mature and late-successional whitebark pine stands in the Canadian Rockies provides a summary of the stem size distribution for Alberta (Table 2). In these data the greatest number of individuals occurred in the two immature size classes (i.e., trees with DBH less than 11 cm): the seedling size class and the 0 – 10 cm DBH size class. Since few whitebark pine individuals reach sexual maturity at less than 30 years of age (see the Conservation Biology section above), only a small proportion of mature trees will have stems with a DBH smaller than 11 cm (Perkins 2001, Ettl and Cottone 2004). This means that only about 22% (263 stems/ha) of the total population is capable of producing seed.

The provincial population size is estimated to be between 28.9 and 187.8 million mature trees, based on the average number of mature trees per hectare and the two estimates of area of occupancy (1099 km^2 and 7148 km^2). Although there is considerable uncertainty associated with these estimates (including inventory inaccuracies and under-sampling), the numbers provide a context within which to view the population stress and decline.

Table 2. Stems per hectare for live whitebark pine cohorts in Alberta (n = 72 stands); data from Smith et al. (in press).

	DBH classes (cm)									
	Seedlings	0-10	11-20	21-30	31-40	41-50	51-60	>60	Mature Total	Overall Total
Mean Stems/ha	398.7	511.3	184.3	56.7	15.1	4.2	1.4	1	262.7	1172.7
Standard Error	68.7	60.8	17.7	7.1	3	1.2	0.7	0.5	30.2	159.7
Minimum	0	0	0	0	0	0	0	0	0	0
Maximum	4476.2	3400	818.2	240	101.3	57.1	40	25.3	1281.9	9158.1
95% Confidence Interval	136.9	121.2	35.4	14.1	6	2.4	1.4	1	60.3	318.4

2. Population trends **-** Although the average distributions of stem sizes discussed here would not be uncommon for apparently stable timberline tree populations, Canadian whitebark pine populations are in decline. The principal cause of mortality is the introduced pathogen, white pine blister rust (Stuart-Smith 1998, Campbell and Antos 2000, Wilson et al. 2002, Zeglen 2002, Smith et al. in press). Most mature trees infected with blister rust initially suffer loss of reproductive potential, followed by mortality over a shorter period of time than would occur naturally. Larger trees also experience a higher incidence of infection (Smith et al. in press), thus hastening the loss of the population's future reproductive potential.

In Alberta, Smith et al. (in press) sampled 72 stands over the northern, central, and southern regions of the province. Only four of these stands were uninfected by white pine blister rust. The proportion infected with this disease in the northern region, Jasper National Park and the surrounding area, had a higher average value (approximately 60%) than the levels of infection found in British Columbia (see below). In comparison, the rate of infection in the central Rockies region (approximately 16%) was well below the British Columbian provincial average. The southern Rockies region, in and around WLNP, had the highest overall infection in the Canadian distribution of whitebark pine, at an average of 73%. Alarmingly, this region also had the highest average mortality of 61%. This work confirmed Stuart-Smith's (1998) findings that the majority of severely infected whitebark pine stands and those with the highest mortality were found in the southern region of the Canadian Rockies in WLNP.

A similar survey of whitebark pine in provincial protected areas has shown low levels of infection in Willmore Wilderness Park and Whitegoat and Siffleur Wilderness Areas (K. Ainsley and A. Benner, unpubl. data). Mortality and infection rates were highest in protected areas found in the southern Alberta Rockies.

Unfortunately, there is little evidence that a rescue effect (the process by which immigrating propagules mitigate population decline) for Alberta or British Columbia can occur from the United States. All of the regions sampled in British Columbia during the most recent province-wide survey had some level of rust infection. Zeglen (2002) examined 483 stands over the major mountain ranges in B.C., where the forest district levels of infection ranged from 18% to 53% (average 34%). He uncovered the general west to east trend of increasing average blister rust infection. In the same stands, Zeglen (2002) estimated a range of whitebark pine mortality caused by blister rust between 4% and 22% (average 10%) and a range of mortality from all causes between 6% and 31% (average 19%). These estimates coincide with Campbell and Antos' (2000) earlier study that examined 54 stands within British Columbia (50 infected) where infection ranged between 0 and 100% (average 33%) and total mortality ranged between 0 and 64% (average 21%).

Areas in Montana, Idaho, and Washington have some of the worst cases of blister rust infection and mortality. Keane and Arno's (1993) study in western Montana provides perhaps the best documentation for the severity of decline in whitebark pine populations as a result of blister rust infection. These authors re-measured their permanent plots in this study (n=17) and found an average mortality rate of 42% over 20 years. Ettl and Cottone (2004) have recently modelled the potential extirpation of the species from Mt. Rainier National Park in Washington. They used a spatially explicit demographic model to show that an initial population of approximately 38 000 individuals has a 94% chance of being reduced to fewer than 100 (> 99.8% decline) in 175 years, a period of less than one generation of the species. These authors conclude that without the presence of blister rust resistance in whitebark pine populations, extinction of the species may occur throughout most of its range.

An Alberta estimate of whitebark pine mortality rate comes from eight permanent plots that Kendall (2003) installed in WLNP during 1996, and re-measured in 2003. Mortality at this location increased from 26% to 61% in seven years—over twice the yearly mortality rate reported by Keane and Arno (1993) (5% compared to 2.1%) (Smith et al. in press). Because we have some relatively complete whitebark pine stand mapping for WLNP, and a recent quantitative inventory in an adequately sized sample of these stands (n = 20, a subset of the 72 Alberta-wide sample [Smith et al. in press]), it is also possible to estimate the average density of mature stems (149 stems/hectare). If we multiply this value by the local area occupied by whitebark pine in WLNP (3775.3 hectares), we get a population estimate for the regional WLNP area starting in 2003 (Table 3). This makes it possible to estimate

Table 3. Estimates of mature whitebark pine population decline for Waterton Lakes National Park region over 100 years. Iterations are based on an r of 5% decline per year (see text for details).

Year (N_t)	Population size	Percent of original population
2003	562 520	100.0
2013	336 801	59.9
2023	201 655	35.8
2043	72 291	12.9
2053	43 283	7.7
2063	25 915	4.6
2083	9290	1.7
2103	3330	0.6

population decline over the coming years using a standard geometric population growth model (COSEWIC 2004, Molles 2005):

$$N_t = N_o r^t$$

In this formula, N_t is the number of individuals at time t, N_o is the initial number of individuals, and r is the rate of change (in this case 5%). Clearly, the rapid reduction of mature individuals, even within the first 20 years of this simulation, suggests that this pine species faces overwhelming challenges to remaining on the southern Alberta landscape in absence of any natural resistance to white pine blister rust (Table 3). This model assumes a constant rate of decline (or growth), which is unrealistic over the long term (Molles 2005). Sadly, it is likely that the 5% decline may increase over the short term (5 – 20 years) in WLNP as the high numbers of live infected individuals succumb to the disease.

To put the model results into context, it is worth noting that the whitebark pine population in WLNP has the highest rate of infection, so a lower rate of population decline may be expected in northern and central regions of Alberta, where the infection rate is lower.

STATUS DESIGNATIONS*

1. Alberta - Using NatureServe methodology, the Alberta Natural Heritage Information Centre (ANHIC) ranks the species as S2 (Gould 2006). The Alberta General Status of whitebark pine is *May Be At Risk* because of extensive infection and subsequent mortality from white-pine blister rust throughout its narrow Alberta range, as well as additional mortality and threats from mountain pine beetle (Alberta Sustainable Resource Development 2007b).

2. Other areas - Using NatureServe methodology, whitebark pine is considered S4 in British Columbia, Montana, Oregon and Idaho, and S3 in Wyoming (B.C. Conservation Data Centre 2007, NatureServe 2007). In Washington, California and Nevada, the species has yet to be ranked (NatureServe 2007). Whitebark pine is given a global ranking of G4 by NatureServe (2007), based on the individual provincial and state S-ranks. This means that the species is considered "uncommon but not rare; some cause for long-term concern due to declines or other factors." However, the species was assessed as *vulnerable* (VU A1c) in 2006 by the International Union for Conservation of Nature and Natural Resources (Conifer Specialist Group 1998). This indicates that the species is considered at "high risk of extinction in the wild in the medium-term future" (IUCN 2002).

RECENT MANAGEMENT IN ALBERTA

Parks Canada initiated conservation efforts for whitebark pine on federally administered land in the mid-1990s (Stuart-Smith 1998). Wilson and Stuart-Smith (2002) suggested a number of goals aimed at improving conservation efforts for the species, including improving stand inventories, seed collection, and prescribed burning (to improve regeneration opportunities for potentially resistant genotypes). To date, some progress has been made on several of these goals. Seventy-two permanent forest health monitoring sites have been set up in Alberta to provide further information on stand and population trends (Smith et al. in press). Two years of blister rust-resistant tree identification and seed collection have occurred in WLNP, including the use of anti-aggregation pheromones to protect potentially blister rust-resistant seed-producing trees from mountain pine beetle attack (Smith and Backman 2006). Efforts are being made in WLNP to set up a longer term seed collection and blister rust screening program. Furthermore, there have also been 14 burn-monitoring sites established

* See Appendix 1 for definitions of selected status designations.

within national parks to help evaluate the success of prescribed and naturally occurring fire for improving whitebark pine recruitment (B. Wilson, unpubl. data). One prescribed fire, near Helen Lake in Banff National Park, has been completed.

A provincial Whitebark and Limber Pine Management Group, including representation from Alberta Sustainable Resource Development (Forests Division, Fish and Wildlife Division); Alberta Tourism, Parks, Recreation, and Culture; Canadian Forest Service; and Parks Canada, has been meeting for the past several years to identify and address provincial management needs for these two species. Some conservation efforts are already underway and include Verbenone trials (for mountain pine beetle control), support of various research projects, forest inventory, health monitoring, incorporation of these species' needs into planning for prescribed burns, cone collection, and initiation of genetic work.

SYNTHESIS

The alarming rate at which blister rust alone is reducing whitebark pine populations presents a gloomy picture for the future of the species in Alberta and elsewhere. Originally, there was the suggestion that the adverse environmental conditions (cool temperatures, shorter growing seasons, and greater aridity) in the extremes of whitebark pine's distribution might provide some refuge for the species from blister rust infection (Hoff and Hagle 1990). However, we now know that these conditions only slow the spread, as variation in climatic patterns appears to have allowed rust infection into most of the pine's natural range (Kendall and Keane 2001). The greatest hope for the species is the occurrence of some naturally blister rust resistant phenotypes in the population, and that we can identify these on the landscape for future seed collection, seedling propagation, rust screening, and replanting efforts.

Therefore, a number of efforts need to be undertaken for effective conservation and restoration of Alberta's whitebark pine:

1. A detailed inventory of the species is required throughout Alberta. The current Alberta Vegetation Inventory (AVI) poorly represents the occurrence and abundance of whitebark pine and may not include coverage of timber licensees operating in high country on the East Slopes.
2. A long-term rust-resistant tree identification and seed collection program needs to be initiated on provincial lands and other areas. This should be started in areas where blister rust infection is high enough to enable successful selection of resistant candidates from susceptible individuals that have yet to be infected or show considerably less canker development than surrounding trees (Mahalovich and Dickerson 2004).
3. Seeds from individual trees need to be identified using a storage, propagation, and blister rust screening process. Progeny of phenotypically resistant trees that show measurable resistance to induced infection could then be planted out in natural areas where infection and mortality are greatest (Hoff et al. 2001, Mahalovich and Dickerson 2004, Schwandt 2006).
4. Enhanced information exchange between land managers working in Alberta's high elevation forests is required. It is important to identify the most appropriate stand manipulations (e.g., different silvicultural prescriptions, prescribed fire) that encourage the maintenance of a stable or increasing whitebark pine population in the medium to long term. These strategies can be compared to, and developed with, other national and international efforts aimed at restoring the vital functions of whitebark pine ecosystems.

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Appendix 1. Definitions of selected legal and protective designations.

A. The General Status of Alberta Wild Species 2005 (after Alberta Sustainable Resource Development 2007b)

2005 Rank	**1996 Rank**	**Definitions**
At Risk	Red	Any species known to be *At Risk* after formal detailed status assessment and designation as *Endangered* or *Threatened* in Alberta.
May Be At Risk	Blue	Any species that may be at risk of extinction or extirpation, and is therefore a candidate for detailed risk assessment.
Sensitive	Yellow	Any species that is not at risk of extinction or extirpation but may require special attention or protection to prevent it from becoming at risk.
Secure	Green	Any species that is not *At Risk*, *May Be At Risk* or *Sensitive*.
Undetermined	Status Undetermined	Any species for which insufficient information, knowledge or data is available to reliably evaluate its general status.
Not Assessed	n/a	Any species that has not been examined during this exercise.
Exotic/Alien	n/a	Any species that has been introduced as a result of human activities.
Extirpated/Extinct	n/a	Any species no longer thought to be present in Alberta (*Extirpated*) or no longer believed to be present anywhere in the world (*Extinct*).
Accidental/Vagrant	n/a	Any species occurring infrequently and unpredictably in Alberta, i.e., outside its usual range.

B. Alberta Wildlife Act/Regulation

Species designated as Endangered under Alberta's *Wildlife Act* include those listed as *Endangered* or *Threatened* in the Wildlife Regulation.

Endangered	A species whose present existence in Alberta is in danger of extinction within the next decade.
Threatened	A species that is likely to become endangered if the factors causing its vulnerability are not reversed.

C. Committee on the Status of Endangered Wildlife in Canada (after COSEWIC 2006)

Extinct	A species that no longer exists.
Extirpated	A species that no longer exists in the wild in Canada, but occurs elsewhere.
Endangered	A species facing imminent extirpation or extinction.
Threatened	A species that is likely to become endangered if limiting factors are not reversed.
Special Concern	A species that may become threatened or endangered because of a combination of biological characteristics and identified threats.
Not at Risk	A species that has been evaluated and found to be not at risk given current circumstances.
Data Deficient	A category that applies when the available information is insufficient to a) resolve a species' eligiblity for assessment or b) permit assessment of a species/ risk of extinction

Appendix 1 continued.

D. Heritage Status Ranks: Global (G), National (N), Sub-National (S) (after Alberta Natural Heritage Information Centre 2006a, NatureServe 2007)

G1/N1/S1	5 or fewer occurrences or only a few remaining individuals. May be especially vulnerable to extirpation because of some factor of its biology.
G2/N2/S2	6 to 20 or fewer occurrences or with many individuals in fewer locations. May be especially vulnerable to extirpation because of some factor of its biology.
G3/N3/S3	21 to 100 occurrences; may be rare and local throughout its range, or in a restricted range (may be abundant in some locations). May be susceptible to extirpation because of large-scale disturbances.
G4/N4/S4	Typically > 100 occurrences. Apparently secure.
G5/N5/S5	Typically > 100 occurrences. Demonstrably secure.
GX/NX/SX	Believed to be extinct or extirpated; historical records only.
GH/NH/SH	Historically known; may be relocated in the future.
G?/N?/S?	Not yet ranked, or rank tentatively assigned.

E. United States Endangered Species Act (after National Research Council 1995)

Endangered	Any species which is in danger of extinction throughout all or a significant portion of its range.
Threatened	Any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

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