Gene Conservation Plan for Native Trees of Alberta

Second Edition

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Preface

This plan was initially developed by Forestry Division of Alberta Agriculture and Forestry and the Parks Division of Alberta Environment and Parks to fulfill a formal commitment to collaborate on provincial forest genetic resource conservation at the direction of the Alberta Forest Genetics Resource Council.

Updates to this edition include changes to taxonomy, the protected areas landbase, species status updates, current information on genetics, and developments in provincial organizational structure, policy and implementation.

The plan is a technical document intended to complement and align with existing policy, particularly the Forest Genetic Resource Management and Conservation Standards, and the Protected Areas Strategy. It provides a framework for tree gene conservation and an implementation plan for a provincial network of in situ reserves for 32 native Alberta tree species. Partners in implementation of the plan include Alberta Agriculture and Forestry and Alberta Environment and Parks, and forest companies involved in tree improvement activities with approved Controlled Parentage Programs.

The provincial government holds the primary responsibility under the plan for establishment of in situ reserves for populations of non-commercial species, and commercial species not covered under commercial tree improvement programs. Companies involved in tree improvement have the primary responsibility to establish and monitor reserves for species and populations covered under approved Controlled Parentage Programs.

The plan will be refreshed periodically to incorporate updates in the protected areas network, species' biology and status, and monitoring results. Lands with significant conservation values outside the jurisdiction of the province, but within Alberta, are also included in this assessment: At present, there is limited information regarding the range and biology of some species. For uncommon, patchy, and rare species, expert knowledge is essential to identify populations and conservation gaps as there are too few records to support accurate habitat modelling. Where areas identified as important to fill in situ gene conservation gaps fall outside national and provincial parks and Crown land, there are opportunities to work with partners such as habitat stewardship organizations and land trusts to establish covenants and conservation easements.

Executive Summary

Genes provide the potential of organisms to adapt to their environments. The genes of Alberta's 32 native tree species are a heritage resource reflecting evolution in changing environments. Climate change impacts the persistence and ranges of species, and the assemblages that form ecological communities. The goal of this plan is to conserve the range of genetic variation of indigenous tree species. This is essential for the long-term survival of species, provided suitable habitat is available to support viable populations over the long term.

Some widespread species have small and isolated populations. Small population size may make these vulnerable to genetic impacts leading to their extirpation or maladaptation. These cases may merit conservation measures to sustain unique populations or isolated populations with important ecological value. Several tree species have range limits in Alberta, leading to geographically peripheral outlier populations that genetically differ from the core of the range because they have frequencies of genes that differ from the core population, or may have less genetic diversity than the core. These species may have well conserved and more robust populations across an adjacent administrative boundary. While it is impossible and impractical to take action to conserve every small population of all species, some are known to have unique attributes or support key ecological functions that would disappear in the absence of those keystone tree species and those may be the focus of conservation efforts, particularly for species at risk.

The in situ gene conservation plan has four objectives:

- maintain genetic diversity of the wild populations as the raw material for evolution,
- maintain populations of known exceptional genetic value,
- provide genetic reference points for genetic diversity and adaptive traits, and
- provide a reservoir of genetic variation for use in scientific study, education and tree improvement.

Detailed knowledge of patterns of genetic variation for tree populations across Alberta is available for commercial species, but limited for most non-commercial species. Closely related species with similar life history traits can be used as surrogates where data are available. Subregional and regional biophysical land classification units (i.e., Natural Subregions) may be used for conservation planning in lieu of population genetic data, based on known clinal adaptation patterns.

Implementation of the plan involves the following strategies and steps:

- Delineate the spatial distribution of each species based on inventory, climate, and habitat data.
- Review species characteristics and distribution by Natural Subregion.
- Identify those species/subregion combinations that data suggest are adequately protected in existing conservation sites such as existing protected areas, tree improvement related gene conservation reserves and inoperable forestry areas.
- Identify and prioritize species/subregion combinations for further work on in situ gene conservation sites. In priority order:

  - species at risk,
  - species with vulnerable or small populations in Alberta,
  - species with rare or restricted habitats, and
  - widespread and abundant species (including those subject to conservation measures as part of tree improvement programs).
- Work to secure additional protection where needed including for species or populations requiring active in situ management.
- Develop brief plans for management of protected populations.
- Follow-up with reporting and monitoring every ten years.
- Every 10-20 years reassess the need for and representativeness of the spatial reserves for gene conservation.

This large task will be phased in over 10 years and re-evaluated on a 10-year cycle based on monitoring results and current scientific literature. Efforts to fill gaps in the network of protected populations will be concentrated on provincial public lands. Complementary efforts will be needed where candidates for protection are on federal or private lands, subject to agreements with other agencies and landowners.

Acknowledgements

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This updated and revised edition was drafted by Jodie Krakowski. Brad Tyssen contributed spatial data analysis, Marge Meijer and Lorna Allen provided external reviews, and Deogratias Rweyongeza provided internal review. Joyce Gould, Elisabeth Beaubien, and Derek Johnson contributed helpful comments and advice.

1 Introduction

Genes provide the potential of any organism to adapt to its environment. For Alberta, the genes of native trees are a heritage resource reflecting evolution in past and contemporary environments.

Gene and species distributions reflect changes since the recession of glaciers 11,000 years ago, and the glacial periods before that. Unglaciated refugia along the patchy ice-free corridor east of the Rocky Mountains, nunataks above the glaciers, and populations south of the ice sheets allowed genes to persist and recolonize species' current ranges, leaving genetic signatures of these migrations.

Recent and anticipated climate change has already impacted species' distributions and their interactions with other species. Conserving genetic variation is a key tool for the long-term survival of species. Population demographics and habitat availability are other important pieces of the puzzle.

Land use also affects genetic resources. Land clearing may extirpate or reduce outlying populations at the margins of species' ranges that may be genetically unique, affecting their persistence. Artificial regeneration of forests change the species composition and allele frequencies, cumulatively altering the population genetics at a landscape scale over time; however, in Alberta regulations and standards require genetically diverse and locally adapted material and native species to be planted. Wildland fire suppression, natural disturbance, and changes in natural drainage all have the potential to affect species demographics and population genetics of trees.

Given this dynamic situation, explicit attention to forest gene conservation is important as the full range of genetic diversity may not be preserved without a plan, limiting future adaptation. Most native trees of Alberta have fairly high genetic diversity within populations and species, and limited differentiation between populations. These characteristics lend some resilience to changing conditions, and provide considerable flexibility in conservation and management options.

1.1 Tree gene conservation in Canada

Canada has 396 million hectares of treed land (NRCan 2016) that represents about 10% of the world's forests (FAO 2016). The importance of tree gene conservation in relation to forestry practice has long been recognized (Fowler and Yeatman 1973). The national program for Conservation of Forest Genetic Resources in Canada (CON**FOR**GEN) is spearheaded by the Canadian Forest Service, based at the National Forest Genetic Resources Centre in Fredericton, New Brunswick.

The main responsibility for conservation of genetic resources of trees lies with provinces and territories under their land and forest management mandates. Status of forest genetic resource conservation varies across Canada. CON**FOR**GEN is responsible for summarizing provincial and territorial reporting as part of Canada's obligations under various biodiversity conventions. The most recent is *Report on the State of Canada's Forest Genetic Resources* (Beardmore et al. 2012).

1.2 History of tree gene conservation in Alberta

Forests occupy 38 million hectares, 58% of Alberta. Forestry revenues contribute approximately $6.3 billion per year to the provincial economy (Carlier 2018; NRCan 2016). Approximately 84,000 hectares of forests are harvested and 77 million seedlings are planted annually in Alberta. Ecosystem services are valued at $5,800 to $26,800 per hectare per year for the boreal, $42,000 per hectare per year for the montane, and $26,600 per hectare per year for the subalpine (TD Economics & Nature Conservancy of Canada 2017).

As of August 2018, Alberta has 482 protected areas covering 4.2 million hectares. A 2006 report (ATPR 2006) valued its direct revenue of $1.1 billion with indirect benefits of $1.2 billion, the values of which certainly have increased since then. Categories range from ecological reserves, which have the highest level of protection, to provincial recreation areas which have the lowest level of protection and are primarily focused on recreational amenities rather than environmental protection. Many of these parks have significant tree populations that contribute to the in situ conservation of tree genetic resources. Alberta's parks network contains:

- 15 ecological reserves,
- 3 wilderness areas,
- 33 wildland parks,
- 1 Willmore Wilderness Park,
- 76 provincial parks,
- 2 heritage rangelands,
- 138 natural areas,
- 204 provincial recreation areas, and
- 10 Section 7 lands allocated and managed as protected areas.

Alberta's five National Parks cover 6.3 million hectares, with extensive forested areas. Protected areas provide a benchmark to compare the status and condition of managed and unmanaged areas over time.

Conservation of wild forest genetic resources is an integral part of sustainable forest management and protection of heritage natural resources in Alberta. The former program is part of the mandate of Alberta Agriculture and Forestry and the latter falls under the mandate of the Parks Division of Alberta Environment and Parks. Species at risk are covered under both provincial and federal legislation, depending which jurisdiction they occur in. The Wildlife Act is administered provincially by Alberta Environment and Parks, and the Species at Risk Act is administered federally by Environment and Climate Change Canada.

The concept of sustainable forest management (SFM) originated at the United Nations Conference on Environment and Development held in 1992 at Rio de Janeiro, Brazil. It was endorsed by the Canadian Council of Forest Ministers (CCFM) and entrenched in Canada's National Forest Strategy Sustainable Forests: A Canadian Commitment (CCFM 1992a), followed by the Canada Forest Accord on Sustainable Forest Management (CCFM 1992b) which was signed by the Alberta government in 1992. The goal of

SFM is to maintain and enhance the long-term health of forest ecosystems for the benefit of all living things, both nationally and globally, while providing environmental, economic, social and cultural opportunities for the benefit of present and future generations. Implementation of SFM is guided by a framework of criteria and indicators, recently updated to incorporate climate change (CCFM 2006; Williamson and Edwards 2014). Maintenance of biological diversity, including genetic diversity, is a key criterion. It recognizes that "Genetic diversity, or the variation of genes within a species, is the ultimate source of biodiversity at all levels; it is the material upon which the agents of evolution act. Loss of variation may have negative consequences for ecological fitness and prevent adaptive change in populations" (CCFM 2006).

The status of conservation efforts for native tree species within each ecozone (in Alberta, analogous to Natural Region) is a core indicator for the maintenance of genetic diversity. Alberta has committed to SFM by adopting most elements of the Canadian Standards Association SFM framework and indicators in the Alberta Forest Management Planning Standard (ASRD 2006). Most managed forest lands in the province are certified for sustainability and subject to compliance audits. Integrated land management principles under the Alberta Land Stewardship Act also follow principles of sustainability for land use planning and management, adopting regional targets and indicators. Alberta Forest Genetic Resource Management and Conservation Standards (FGRMS) provide specific guidelines for incorporating and evaluating genetic resources conservation in operational tree improvement and forest management.

Early programs for provincial forest conservation were largely driven by heritage and scenic resources protection. Over time, protection for rare and endangered species and their habitat, and preserving the inherent value of genetic resources became objectives. A systematic effort for forest tree gene conservation was started in 1975 as part of the provincial tree improvement program focused on commercial forestry species. Since then, the urgency and importance of forest gene conservation of wild forests have increased because of the extent of anthropogenic and natural disturbances, land use change, and climate change impacts.

1.3 Goal, objectives, and strategies

This report discusses and details a plan to achieve the goal for conserving the population genetic diversity of 32 native tree species and their natural hybrids across Alberta. The objectives of the *Forest Tree Gene Conservation Plan for Alberta* are:

- maintain genetic diversity of the wild populations as the raw material for evolution,
- maintain populations of known exceptional genetic value,
- provide genetic reference points for genetic diversity and adaptive traits, and
- provide a reservoir of genetic variation for use in scientific study, education and tree improvement.

Strategies to achieve these objectives should:

- assess the adequacy of existing protection for native tree gene resources,
- identify gaps in existing protection,
- identify candidate sites to fill gaps in existing protection,

- co-ordinate establishment of selected sites,
- work with responsible agencies and industry to maintain adequate protection for all gene conservation sites, and
- periodically (every 10 to 20 years) evaluate whether environmental and climatic changes have shifted species distributions within reserve boundaries such that a realignment or change in location is needed.

1.4 Scope of the plan

This plan identifies current and proposed in situ gene conservation sites for native tree species across Alberta. It also summarizes the concepts and need for gene conservation, proposes an Alberta approach, and reviews the Alberta species to determine conservation gaps and priorities. Proposals for additional protection will be limited to provincial public lands unless there is specific interest from other parties. Other lands that may support tree populations suitable for in situ gene conservation include:

- National Parks and Heritage Sites, National Wildlife Areas and National Migratory Bird Sanctuaries which already have some degree of federal protection;
- lands allocated to First Nations provide opportunities to work cooperatively with indigenous communities; and
- private lands where there may be opportunities to work with non-governmental organizations, land trusts, regional governments and private individuals through the development of conservation easements, covenants or other similar agreements.

2 Genetic Resources Conservation — Concepts and Principles

2.1 Scientific concepts

Populations of native tree species often differ genetically in different environments

The relationship between the distribution of plants and geography has been recognized for 25 centuries (Woodward 1987). The influences of genes and genetic processes on plant distributions have been illuminated over the past 150 years, and over the past few decades genetic technology has uncovered many details of evolutionary and adaptive patterns.

Knowledge of genetics is fundamental to conservation of gene resources. Conifers contain nearly 30,000 functional genes, about the same number as humans, but have about seven times more DNA because of their evolutionary history and long life spans. Organisms sometimes have alternate forms (alleles) of a gene caused by slight differences in the DNA sequence in that gene. Most alleles have no known effect and result in the same gene product, function, and appearance of the organism. In other cases, these differences do cause a functional change, resulting in a visible difference in the trait, such as leaves with toothed or smooth edges.

The genotype, or unique combination of genes, an individual has is affected by the environment the individual develops in. Genes and their products may be expressed at different life stages, or triggered by environmental effects, such as an insect attack, or drought stress. The combined interaction of the genotype and environment results in the expression of the individual phenotype, which can also be considered as a combination of the observable traits. The study of adaptive traits of populations in relation to their environment is called genecology.

The fitness effects of alleles may be neutral, positive, negative, and even change depending on the environment. There are often trade-offs, for instance trees that grow more slowly may have more robust root systems and be more drought tolerant; trees that have faster diameter growth tend to have less dense wood. Traits may be adaptive such as growth and frost hardiness, or non-adaptive such as needle colour or leaf margin shape.

Some traits have high heritability and their expression is less influenced by the environment. The inheritance of qualitative traits is influenced by one or a few major genes, and these traits often show categories of expression, such as disease resistance that may have resistant or susceptible phenotypes. The vast majority of traits in trees are quantitative, showing influence by hundreds or thousands of genes with heritability ranging from small to miniscule effects which all combine in the continuous expression of the trait. The expression of these traits is moderately affected by the environment. Height, phenology, cold hardiness, drought tolerance, wood properties, and growth form are all quantitative traits showing a continuous or clinal pattern of variation along an environmental gradient or spatial distance.

The combined variation among all the genes of an organism is genetic variation. The total amount of genetic variation among individual trees in a population, and among populations within species is genetic diversity. Genetic variation is measured at various scales: species, populations within a species, and individuals within a population or species. The proportion of variation between versus within populations is a key index of how tightly adapted a population is to its environment. That variation is the raw material upon which evolution acts to drive genetic changes over successive generations. Genetic diversity is essential for populations to persist, adapt, and reproduce under changing environmental conditions, especially over the very long lives of trees. Patterns of diversity also reflect prior demographic changes like range shifts with climate change, recolonization after glaciation, or a rapid population expansion. Very small populations are sensitive random events (or by management actions) causing changes in allele frequencies and often have lower diversity than larger populations.

For many tree species, the earliest genetic studies involved collection of seeds from throughout the species' range and testing trees from those seeds in a series of common test environments, called common garden or provenance testing. Because environmental variation is minimized at the test site, differences in performance are attributed to genetics. Provenance trials are the main method used to delineate seed zones today. They quantify how far populations can be moved from their origins before they grow poorly, expressing maladaptation because they have been moved too far climatically or ecologically. Provenance tests also provide important data on projected impacts of climate change on populations because moving seed sources from sites that represent historic climates at collection sites to future climates at test sites simulates climate warming.

Gene conservation of representative populations adapted to different environments

To conserve genes and allele frequencies of native trees in Alberta, the association of genetic differences with environment means that genetic resources must be represented in several environments. The distribution of genetic variation across a wide range of environments should maintain adequate diversity for adaptation. Environmental classification by Natural Subregions provides a robust level of environmental differences to select populations from.

Status, time scales and disturbance

While formal reserves such as protected areas provide the most security for conservation, genes can still be effectively conserved in situ in temporary long-term reserves such as unharvested buffers or inoperable areas in the operational forestry land base which are in place for a full forest rotation. Some naturally regenerated areas, or cutblocks planted with local seed in managed forests may also fulfill conservation objectives as the new stand descends from the same gene pool as the parent stand (depending on the cutblock size and shape). Alberta does not have a network of protected areas at this time that would fulfill the objectives of this plan. As long as representative wild populations of adequate size remain distributed across the province, there is a higher likelihood that their genetic potential will be undiminished, indicating the importance of gene conservation beyond protected areas.

The time period for a tree gene conservation reserve in a typical forested ecosystem should not be less than 50 years to ensure all individuals in the target population contribute to the next generation. For early seral species, this may be shorter, and the population may rely on disturbance to maintain early seral characteristics and reproduce successfully. Redundancy is important in the event one reserve is destroyed by wildfire, accident, trespass, or other disturbance. In the event of disturbance or evidence of maladaptation due to climate or environmental change, it may be prudent to relocate a reserve to a viable, healthy population that is better adapted.

Conserving genes of native tree species using principles of quantitative genetics and ecology

This plan focuses on conserving the genes within populations of native trees. Trees are often keystone species in ecosystems that include many other species, and provide a diverse range of ecosystem services.

Quantitative genetics studies provide guidelines on maintaining genetic variation in different population sizes. Where genotypic data for a certain species are lacking, data on related species with similar life history traits may be used for guidance. Alleles may be lost due to natural selection or random sampling effects (also called genetic drift). Alleles may be gained through migration and mutation.

Calculations of how many trees are needed to avoid loss of genetic variation typically assume that all individuals have equal reproduction and chance of mating. This is never the case for forest trees, so you always need more trees than the calculated minimum to make up for these differences (El-Kassaby and Cook 1994; Kang 2000). Aitken (2000) concluded, "…as long as the minimum number is in the thousands, rather than the hundreds, and if trees have mutation rates similar to other organisms, genetic diversity will be conserved adequately." Based on studies of outcrossing conifers, Yanchuk (2001) suggests 5,000 reproductively individuals, estimating a population of that size would probably maintain at least five copies of recessive alleles with frequency greater than 0.08. This plan adopts the minimum of 5,000 mature individuals as a conservation objective.

A target of three reserves with 5000 mature individuals per species in each natural subregion where the species occurs should provide long term in situ preservation of genetic resources. Over time, locations and composition of reserves need to be reassessed to determine whether environmental and climatic changes have shifted species distributions within the spatial reserve boundaries such that realignment is needed.

Species and populations have different gene conservation priorities

There are large differences in the risk of significant loss of genetic variability among species and populations of tree species in any given area. One influential factor is a species' natural distribution. Life history traits like fecundity, mating system, and dispersal also affect diversity patterns. Species with large continuous distributions are far less vulnerable to the loss of genetic diversity than those with fragmented distributions of relatively small populations that are poor reproducers and dispersers.

Alberta's species of commercial importance are widely and continuously distributed. There are extensive wild populations maintained in inoperable areas and areas where harvesting is prohibited. Seed banks, repositories of seed dormant in the soil vary with the species: seeds of lodgepole and jack pine can persist for years, even decades, while spruce seed does not last from year to year but it is a prolific seed producer in most years. These factors largely mitigate genetic impacts caused by intensive forest management and wildfire. Currently under 15 per cent of reforestation needs within each region of the province are met with seedlings from seed orchards, which are production plantations representing the best adapted trees selected from a population. Using seed orchards for reforestation is not considered to pose a genetic risk as studies have found orchard seedlings often have genetic diversity at comparable levels to local wild material, and are well adapted to local environments (e.g. El-Kassaby 1992, 2000; Godt et al. 2001).

Pests and diseases may impact the conservation status of species, particularly invasive species where there may be little native resistance. This is the case for endangered tree species whitebark and limber pine, which are threatened by an introduced pathogen against which natural heritable resistance is present, but rare.

Gene conservation must assess the various factors that may compromise genetic variation and focus conservation efforts on species and populations deemed to be most at risk. Careful setting of priorities is required to make conservation as efficient and cost-effective as possible.

2.2 Approaches to tree gene conservation

There are two basic methods of gene conservation: in situ and ex situ

In situ and ex situ conservation methods serve different gene conservation needs and complement each other. It is prudent to have at least some ex situ conservation measures in place to supplement in situ conservation, especially where the existing genetic resources of a protected population are threatened.

In situ gene conservation consists of maintaining wild tree populations in their natural habitats, along with their associated plants, pollinators, dispersers and mycorrhizae, which are influenced by natural evolutionary processes. In situ conservation can be carried out in designated areas such as protected areas and designated tree gene conservation areas. The landscape between formally protected areas often serves an essential role in in situ conservation, sustaining reproduction and gene flow between conservation "islands," and supporting evolutionary processes such as adaptation. A large proportion of certain habitat types are considered inoperable for industrial management so they may serve as de facto conservation areas. If markets or equipment change these areas may be converted to managed landscapes.

Ex situ conservation consists of conserving representative samples of wild tree genes outside their natural habitat. The most common method is collecting representative seed samples from wild populations and storing them in seed banks. Other approaches include tissue culture (propagating cells containing the desired DNA in artificial growth media), cryogenic storage (where living material can be kept dormant for decades or longer at ultra-low temperatures), collecting and storing pollen, collecting and grafting scions (shoot cuttings), and establishing these in arboreta (living tree collections), clone banks. Trees of known origin established in research trials, plantations, seed orchards, provenance trials, progeny trials (where selected trees are tested for heritable traits based on the growth of their offspring), and botanical gardens are also forms of ex situ gene conservation. Some authors (e.g. Blixt 1994; Lipow et al. 2003) have classified progeny trials, clone banks and regional seed orchards within their local adaptive zones as inter situ, indicating that trees are growing in their regional environment to which they are adapted, in a test site but not within their natural habitat. For simplicity they are classified here as ex situ as they represent static archives.

General principles for reserve size and design

The size of an in situ gene conservation reserve depends on the population size of the target species to be conserved and on the density and distribution of the target species within the area. Recruitment, mortality, and disturbance also need to be considered because these alter the numbers of mature individuals of the target species in a reserve. Because resources and space are always limited, there is an inherent trade-off that is made between conserving a target number of individuals, a number of populations, and traits of interest. Understanding the extent to which traits are genetically controlled, and patterns of genetic diversity within a species, enable the most efficient conservation approach.

Optimal reserve design consists of a single unfragmented core area that should be more compact than linear to minimize vulnerability to edge effects, surrounded entirely by a buffer zone of two dominant tree heights or 30 metres whichever is greater (PGYI 2016) in order to mitigate potential impacts of adjacent disturbance such as windthrow following harvest, and to mitigate edge effects on species composition and density. Based on the lack of agreement or scientifically defensible quantitative targets in the literature regarding desirable buffer sizes for in situ plant gene conservation, the above guidance is reasonable to maintain the integrity of the core area.

A core area should contain at least 5,000 mature individuals of the target species and the core and buffer are georeferenced to facilitate relocation and identify potential land use conflicts. Clear field markings are desirable to help relocate boundaries in the field for monitoring. To support sustaining the population over the long term a site with good recruitment potential should be selected. FGRMS does permit forest harvesting within in situ reserves, provided the stand is regenerated with locally collected seed so that the gene pool is maintained; however if all mature trees are removed this would no longer meet the criteria of a long term functional in situ reserve until 5,000 trees mature, although it may still be compliant with the Alberta standard.

Average mature stand densities for target species generally range from 200 to 2,000 stems per hectare in Alberta depending on the proportion of the target tree in a polygon, stand age, management history, and site productivity. This results in a minimum reserve size (core and buffer) of 10.3 hectares (700 stems per hectare if round) to 40.6 hectares (150 stems per hectare if square) (Table 1, Figure 1). Irregular and long shapes, as would be more realistic to align with forest stand polygons, would be more susceptible to edge effects and external impacts, and will need larger areas to maintain reserve integrity.

The surrounding buffer zone protects the core area from edge effects, trespass and other factors that might threaten the target population in the core area, but is smaller than buffers recommended to maintain integrity of functioning ecosystems and wildlife species because the reserve objective is strictly to retain a minimum tree population (e.g., Thorell and Götmark 2010). The buffer area also allows possible extensions of the core area should that become necessary. As harvesting is permitted in the core area, subject to local seed of the same species being used for regeneration, this also applies to the buffer.

Table 1. Reserve size varies with density of target species and shape, based on 30 metre buffer.

	Round				Square			
Density (stems/ha)	**Core area (ha)**	**Core radius (m)**	**Total radius (m)**	**Total area (ha)**	**Core area (ha)**	**Core side length (m)**	**Total side length (m)**	**Total area (ha)**
200	25.0	282.1	312.1	30.6	25.0	500.0	560.0	31.4
300	16.7	230.3	260.3	21.3	16.7	408.2	468.2	21.9
400	12.5	199.5	229.5	16.5	12.5	353.6	413.6	17.1
500	10.0	178.4	208.4	13.6	10.0	316.2	376.2	14.2
750	6.7	145.7	175.7	9.7	6.7	258.2	318.2	10.1
1000	5.0	126.2	156.2	7.7	5.0	223.6	283.6	8.0
1250	4.0	112.8	142.8	6.4	4.0	200.0	260.0	6.8
1500	3.3	103.0	133.0	5.6	3.3	182.6	242.6	5.9
1750	2.9	95.4	125.4	4.9	2.9	169.0	229.0	5.2
2000	2.5	89.2	119.2	4.5	2.5	158.1	218.1	4.8

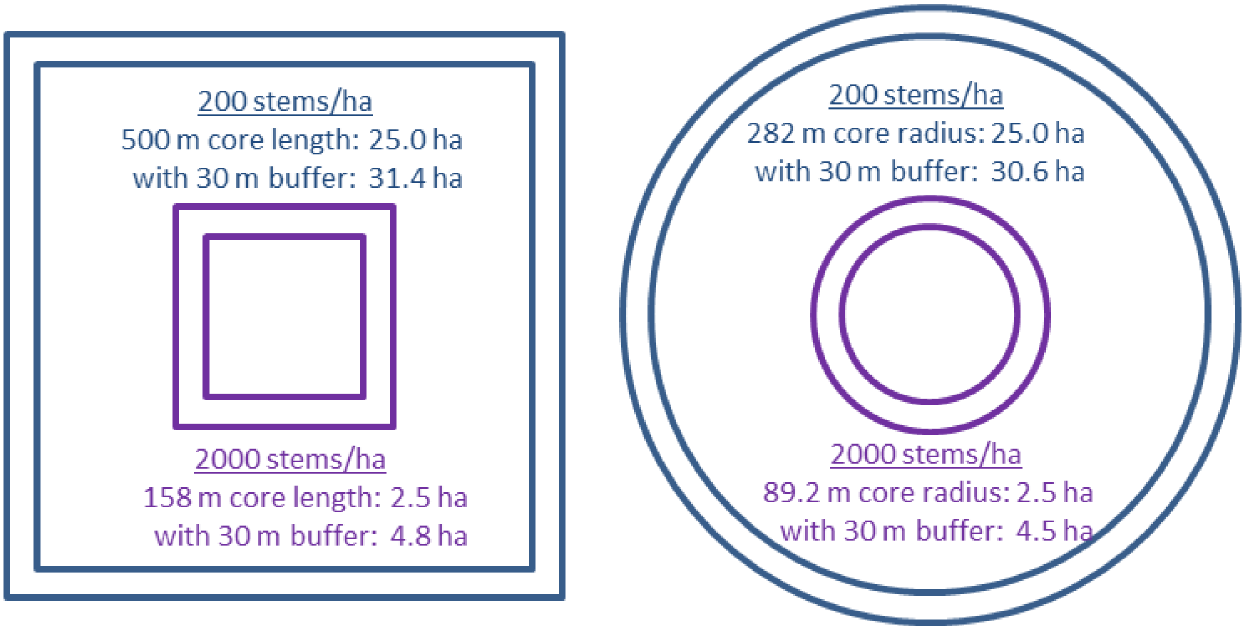

Figure 1. Examples of reserve sizes needed for different density of target species and shape.

Duration and sustainability

Reserves should be monitored every ten years to assess population stability, to determine whether enough individuals are present, and if regeneration appears likely to sustain the population. Reserve boundaries may need to be adjusted over time to accommodate climatic or other changes to ensure that a core population is maintained over the long term. For trees, three generations should be considered to determine if the species is stable, increasing, or declining for adjusting reserve needs, comparable to the International Union for Conservation of Nature and Natural Resources criteria for species status assessment (IUCN 2012). Status assessments can also confirm whether the conservation reserve is still needed.

3 Gene Conservation for Native Trees of Alberta

There are four main objectives for gene conservation of Alberta's native trees.

1. Maintain genetic diversity of the wild populations as the raw material for evolution.

This objective can be largely met for most species by maintaining large or contiguous representative populations of trees in situ. This allows natural selection to proceed and averts loss of genetic variation due to small populations.

For small, patchy, and endangered populations, this objective is more difficult to meet, unless extensive reserves or more active management designed to sustain and regenerate these species are possible. A metapopulation approach where gene flow through a landscape matrix of varying degrees of protection and management may be important in these cases to sustain diversity through migration. It may be necessary to supplement in situ populations with ex situ reserves to sustain allelic diversity over the long term or until endangered species are recovered.

2. Maintain populations of known exceptional genetic value.

Although most adaptive variation in trees is characterized by clinal patterns, populations with exceptional traits are occasionally identified. Resistance to insects and diseases are important examples, as are "correlation breakers," trees that have a unique adaptive portfolio not found in the general population. Sometimes these traits show population-level traits (King and Alfaro 2009), and sometimes they are expressed in individuals. Where there is a high value population, it merits special protection. Conservation of individuals in situ is more challenging as it is not administratively possible to establish spatial protection for each one. In those cases, spatial identification of these high value individuals in land management GIS data sets and field marking is probably the most effective way to avert impacts. Establishing conservation areas so they include as many of these individuals as possible is also a good practice.

3. Provide genetic reference points for genetic diversity and adaptive traits.

Standards for seed collection for managed forest regeneration are designed to maintain the amount of genetic variation present in harvested populations. Seed collection, storage, and nursery practices however all influence alleles in the seedling population such that the frequencies differ somewhat compared to the original forest. Maintaining representative populations of trees in wild and managed forests will provide genetic reference points for genetic diversity and genetic change. This can be achieved through unmanaged areas, inoperable areas, and stand level retention within cutblocks, as well as cutblocks regenerated naturally.

4. Provide a reservoir of genetic variation for use in scientific study, education and tree improvement.

Although there is abundant information on commercial species, many native trees of Alberta lack specific population genotypic and adaptive trait data. Wild populations contain the genetic resources to address such questions should the opportunity arise. The results of scientific study of wild populations of trees inform sustainable forest management. Maintaining genetic diversity is both in the public interest and a requirement of industry as part of provincial forest management. Wild populations provide the genetic raw material for tree improvement for all traits of interest.

4 Species Characteristics and Conservation Needs

A tree is defined as a perennial woody plant at least five metres tall at maturity, whose stem supports a crown. Using this definition, there are 32 native tree species in Alberta, listed alphabetically by common name in Appendix 1. Thorny buffaloberry (*Shepherdia argentea*) and river alder (*Alnus incana* ssp. *tenuifolia*) can grow up to or over five metres, but have not been included here as they are not crown-forming.

This plan summarizes information for a general audience about principal features on autecology (each species' ecological attributes and adaptations), identification, distribution, common associates, reproduction, patterns of genetic variation and hybridization, protection status with respect to gene conservation, and taxonomy. Information is summarized in Appendix 1, based on publications and local expertise. Most non-commercial species have little or no reliable inventory data so expert advice is an important part of this assessment.

Although some species have many reports on genetic variation, not all include material from Alberta. For several non-commercial tree species, no genetic research has been done. Since general patterns of genetic variation among and within tree populations are similar for most species with similar life history traits, related species serve to guide recommendations on gene conservation.

Recommendations for gene conservation are based on the following factors. These helped to guide the assessment of the current status of gene conservation and to identify potential future needs in Alberta:

- rarity of the species,
- mode(s) of reproduction and frequency of natural regeneration,
- patterns of genetic variation,
- populations represented in each Natural Subregion where they occur,
- populations at the periphery of their distribution,
- threats to a species, and
- populations of known exceptional traits.

5 Conservation Units for Planning and Assessment

5.1 Alignment with Alberta ecological framework

Adaptive genetic variation within plant species is often associated with differences in abiotic and biotic factors in the environment such as geography, climate, disturbance patterns, and site ecology. If genotypic and adaptive genetic data is lacking, landscape level ecological units are a reasonable surrogate for forest tree gene conservation units (Bower et al. 2014).

The Alberta hierarchical natural region classification (Figure 2) has six Natural Regions reflecting major biomes, subdivided into 21 Natural Subregions based on differences in vegetation, soils, landscape features, parent materials, land-use and climate (Natural Regions Committee 2006). Natural Subregions present a scale suitable for forest tree gene conservation planning and management (Hamann et al. 2010; Gray et al. 2011, 2016a, 2016b; Liepe et al. 2016). Table 2 lists the Alberta tree species alphabetically by common name, indicates which natural subregions they occur in, and how common they are in each. Common natural hybrids are listed below species but are not included in this plan as natural hybrids are difficult to identify accurately and manage for. Information sources used to compile distribution data are listed in Appendix 2.

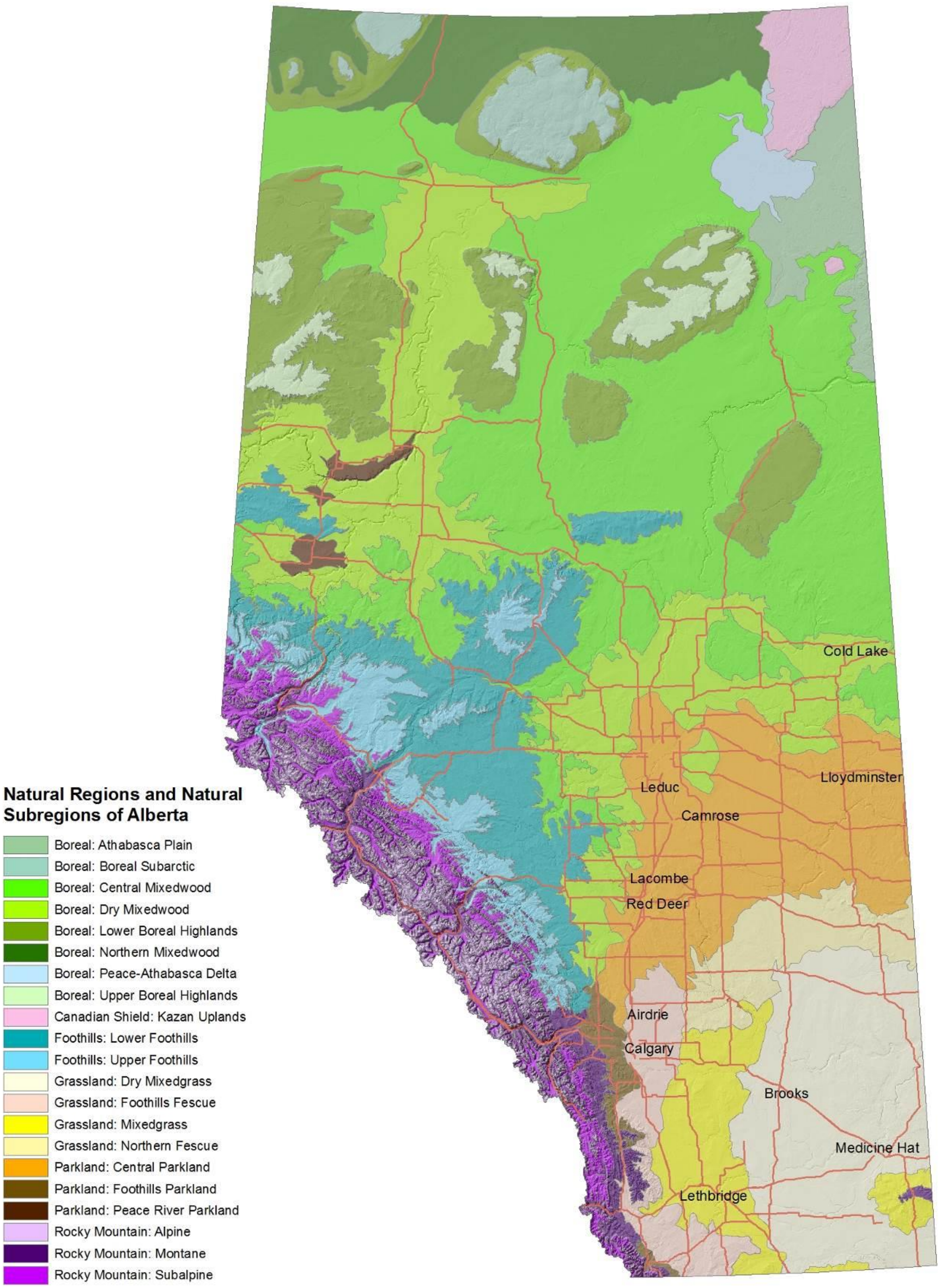

Figure 2. Map of Natural Subregions of Alberta

Table 2. Matrix of species distribution and frequency by Natural Subregion[1]; hybrids[2] in italics. See Figure 2 for Natural Subregions map.

Natural Region	**Boreal**								**Shield**	**Foothills**		**Rocky Mountains**			**Parkland**			**Grassland**			
Natural Subregion	**AP**	**BSA**	**CM**	**DM**	**LBH**	**NM**	**PL**	**UBH**	**KU**	**LF**	**UF**	**A**	**M**	**SA**	**CP**	**FP**	**PRP**	**DMG**	**FF**	**MG**	**NF**
Alaska birch	U	U	U	U	O	U	U	U	O												
aspen	U	U	A	A	A	C	O	U	U	A	O	U	C	U	A	A	A	U	U	U	U
balsam fir			O	U	O	U	U			U	U						U				
balsam poplar	U	U	A	C	C	C	O	U	U	C	O		U	U	U	U	U		U		U
black cottonwood													O								
black spruce	C	A	C	O	C	A	O	A	C	C	A		U	U	U		U				U
chokecherry	O		C	C	U		U	O		C	C		C	U	A	C	C	C	U	U	O
Engelmann spruce											O	U	U	A							
green ash															O			O		U	U
jack pine	A		C	O	U	O			O	U					U		U				
limber pine												U	U	U							
lodgepole pine		O			O			A		A	A	U	A	A							
Manitoba maple															U	U		U		U	
narrow-leaf cottonwood										U									U	O	
paper birch	U	U	O	O	C	O	O	U	U	O	U		U		O		U			U	
peach-leaved willow																		U		U	
pin cherry	U	R	C	C	U	U	C	U	U	O	O		U	O	C	C	C				
plains cottonwood																		U		U	
Rocky Mountain Douglas-fir													O	U		U			U		
Rocky Mountain juniper													U	U				U			
Scouler's willow			U	U			U			U			U								
subalpine fir					U			U		U	O	U	C	A				U			
subalpine larch												U		U							
tamarack	U	U	C	O	C	C	U	O	U	C	O				U		U				
water birch			U	U						U	U		U		U	U		O	U	U	U
western hemlock													R								
western larch													R	R							
western redcedar													R	R							
western white pine													R								
western yew													R								
white spruce	U	O	A	C	A	A	A	A	U	A	O		C		U	U	U				
whitebark pine												C		C							
balm-of-Gilead																		*U*			
hybrid spruce										*O*	*A*		*O*	*O*							
lanceleaf cottonwood																		*U*		*U*	*U*
lodgepole x jack pine		*O*	*O*		*C*	*U*		*C*		*O*											

[1]**A**, abundant: major component of stands; **C**, common: patchy or minor but significant component of stands; **O**, occasional: localized patches or minor or locally significant component in stands; **U**, uncommon: occasional individuals or isolated small populations; **R**, rare: provincially tracked due to limited numbers and/or distribution. Species with limited presence in an ecotone are not listed when they are more common in an adjacent subregion.

[2]Hybrids: balm-of-Gilead is *Populus deltoides* x *P. acuminata*; hybrid spruce is *Picea engelmannii* x *P. glauca*; lanceleaf cottonwood is *Populus angustifolia* x *P. deltoides*; lodgepole x jack pine is *Pinus contorta* var. *latifolia* x *P. banksiana.*

5.2 Objective and priorities for genetic conservation

The objective for gene conservation is to contain at least 5,000 mature unrelated individuals in each of three sites per natural subregion in the core of the species' distribution and up to three sites in peripheral or outlying parts of the range. Known locations will be evaluated with respect to conservation status. Populations that are common or abundant throughout the natural subregion and not at risk are considered secure and no additional conservation area will be designated. If gaps remain, local agency staff will then be asked to propose candidate gene conservation reserves, following criteria in Section 5.2 (e.g., existing protected areas). Government and industry partners in tree improvement projects operating under approved controlled parentage programs are responsible for gene conservation of the target species within the plan area as per provincial standards.

Wherever feasible, gene conservation areas will be selected in order to capture a representative spectrum of genotypic and adaptive patterns. These patterns may be identified based on species-specific data or on data for these patterns in sympatric related species from the literature. For species without supporting genetic data, the species' range will be stratified into habitats by Natural Subregion, incorporating biophysical habitat elements as available, such as soil moisture and nutrient regimes, elevation, aspect, parent material, and riparian areas.

To most efficiently allocate resources for gene conservation, the following factors were considered:

- Core regions of species' distributions should be selected first as these would capture most of the genetic variation in Alberta for a given species. Studies of trees indicate that genetic variation is relatively high in these areas (Gapare et al. 2005; Pandey and Rajora 2012).
- Peripheral populations may be genetically divergent from core populations, particularly in environmentally extreme habitats and populations that have been isolated for many generations. There are two main genetic reasons for differentiation: some may have different alleles than the core population, while populations that are disjunct or at the leading edge of a species' distribution are often genetically depauperate and differ primarily in the frequency of alleles, rather than containing unique genotypes.
- Some populations contain known unique genetic features or individuals with these elements, such as higher levels of disease resistance than in the rest of the range.

Table 3. Considerations for gene conservation by species.

Common name *Scientific name*	**SRANK**[1]	**GRANK**[2]	**Gene conservation considerations**
Alaska birch *Betula neoalaskana*	S5	G5	Alaska birch is present but rarely common in nine Natural Subregions. It hybridizes readily with paper birch and water birch (Furlow 1997). It grows interspersed with other species at moderate to low densities in bogs and poorly drained sites with black spruce, and is uncommon in upland sites where it is grows with white spruce. Alaska birch is not a managed timber species in Alberta, and it is not at risk.
aspen *Populus tremuloides*	S5	G5	Aspen is the most widely distributed native tree species in Alberta, occurring in 19 of the 21 Natural Subregions. It is found on well-drained but moist soils, often in pure stands. It is a vigorous clonal reproducer with frequent seedling establishment. Climate change has been implicated in widespread aspen dieback (Hogg et al. 2002; Woods et al. 2010). It is a managed timber species for pulp with a tree improvement program, and is not at risk.
balsam fir *Abies balsamea*	S5	G5	Found occasionally in two Natural Subregions (Lower Boreal Highlands and Central Mixedwood), and uncommon in six Natural Subregions with disjunct populations in the southwestern portion of the range and an ecotone between the boreal forest and parkland. A species of moist woods, commonly intermixed with poplars and white spruce. Balsam fir is not a managed timber species in Alberta, and it is not at risk.
balsam poplar *Populus balsamifera*	S5	G5	Balsam poplar is widely distributed, found in 18 Natural Subregions, but uncommon in most of the Natural Subregions where it occurs (abundant or common in six). A prolific seed and clonal reproducer, habitat is restricted to riparian areas. Some poplar populations have been impacted by drought and development. It hybridizes easily with other poplar species, is a managed timber species for pulp, and is not at risk.

Common name *Scientific name*	**SRANK**[1]	**GRANK**[2]	**Gene conservation considerations**
black cottonwood *Populus trichocarpa*	S3	G5T5	Black cottonwood occurs in southwest Alberta in the Montane Natural Subregion. A prolific seed and clonal reproducer, habitat is restricted to riparian areas. It hybridizes in Alberta with balsam poplar, is not a managed timber species, and is not at risk although localized drought impacts exacerbated by climate change may affect abundance of Alberta populations.
black spruce *Picea mariana*	S5	G5	Black spruce occurs in most (16) forested Natural Subregions, and is abundant in four. Ecological and genetic variability is fairly low across sampled populations (e.g. Jaramillo-Correa et al. 2004). Range-wide studies have shown clinal variation with no unique ecotypes (Johnston et al. 1990). Black spruce is occasionally a managed timber species in Alberta on upland sites with a small tree improvement program. Often stands are excluded from the harvesting landbase because they typically are bogs and poorly drained sites.
chokecherry *Prunus virginiana*	S5	G5	Chokecherry is common and abundant species across all but the northernmost limit of Alberta. It is a prolific reproducer after disturbance and can persist in an enormous range of habitats, but inventory is generally absent. It is not a managed timber species, and is not at risk.
Engelmann spruce *Picea engelmannii*	S5	G5	Engelmann spruce is abundant in the Subalpine Natural Subregion. It is occasional in the Upper Foothills and uncommon in the Alpine and Montane Natural Subregions. A species of moderate to high elevations - at higher elevations it grows as a krummholz shrub. Hybrids between Engelmann and white spruce are common.
green ash *Fraxinus pennsylvanica*	S2	G5	Native populations in Alberta are considered rare and restricted to the southeastern corner of the province, in mixed stands along river courses in the Dry Mixedgrass Natural Subregion. It is thought that shelterbelt and ornamental plantings have naturalized and interbred and would be impossible to distinguish without genotyping. Green ash is not a managed timber species in Alberta.

Common name *Scientific name*	SRANK[1]	GRANK[2]	Gene conservation considerations
jack pine *Pinus banksiana*	S5	G5	Jack pine is found in nine Natural Subregions although it is abundant, or common, only in the Athabasca Plain and Central Mixedwood subregions. It occurs in pure or mixed stands on sandy or gravelly substrates. There is an extensive hybrid zone with lodgepole pine, extending into B.C. (Cullingham et al. 2012). It is a managed timber species for pulp with a tree improvement program, and is not at risk.
limber pine *Pinus flexilis*	S3	G4	Limber pine, listed as endangered under the *Alberta Wildlife Act*, is a species of dry, exposed rocky slopes and ridges. Occurrences are tracked in ACIMS[4]. It is present and uncommon in three Natural Subregions. It has the same Alberta status and threats as whitebark pine. A status decision is pending federally; COSEWIC[3] recommended Endangered status in 2014. It is not a managed timber species.
lodgepole pine *Pinus contorta* var. *latifolia*	S5	G5	Lodgepole pine is moderate to abundant in eight Natural Subregions, with hybrids as described above for jack pine. It occurs on a wide variety of habitats, in pure to mixed stands. There are some isolated populations along the eastern and northern margins of the species' range (often hybrids) and an outlying population at Cypress Hills. It is a managed timber species with extensive tree improvement programs, and is not at risk.
Manitoba maple *Acer negundo*	SU	G5	Manitoba maple is present but uncommon in four subregions. It grows best on moist, disturbed ground and is often associated with seasonally flooded areas. It is extensively naturalized and sources have been widely mixed following homesteading so distinguishing native sources may be difficult to impossible. Manitoba maple is not a managed timber species in Alberta, and it is not at risk.

Common name *Scientific name*	**SRANK**[1]	**GRANK**[2]	**Gene conservation considerations**
narrowleaf cottonwood *Populus angustifolia*	S3	G5	This species is uncommon in the Lower Foothills and Foothills Fescue and occasional in the Mixedgrass Natural Subregions. It hybridizes readily with other indigenous *Populus* species (Kershaw et al. 2001; Floate 2004) and is difficult to identify as a result. Its northern limit is in Alberta but the range extends to Mexico. A prolific seed and clonal reproducer, habitat is restricted to riparian areas. Some poplar populations have been impacted by drought and development. It is a not managed timber species, and is not at risk.
paper birch *Betula papyrifera*	S5?	G5	Paper birch grows in 15 Natural Subregions but is common only in the Lower Boreal Highlands. The Montane Subregion contains disjunct populations at Cypress Hills and in the Crowsnest area, and in the boreal/parkland ecotone. Populations in stands are usually at low densities. It is a shade-intolerant species, usually found on well-drained sandy or silty soils. Paper birch is not a managed timber species in Alberta although it does get managed incidentally with other deciduous species. For the past decade the rate of paper birch decline has been increasing and has been attributed to severe growing season drought causing increased susceptibility to other pathogens (Woods et al. 2010).
peachleaf willow *Salix amygdaloides*	S3	G5	Peachleaf willow is at the northern edge of its broad range in southeast Alberta and is uncommon in the two Natural Subregions (Mixedgrass and Dry Mixedgrass) where it occurs. Its habitat is restricted to riparian areas. No Alberta sympatric hybrids are reported (Argus 2007). It is not a managed timber species, and is not at risk.
pin cherry *Prunus pensylvanica*	S5	G5	Pin cherry is a locally common and abundant pioneer species that suckers after disturbance on a wide range of well drained sites. Absent to uncommon in non-forested and mountainous regions, it occurs across most of Alberta and extends into the Northwest Territories, but inventory is generally absent. It is not a managed timber species, and is not at risk.

Common name *Scientific name*	**SRANK**[1]	**GRANK**[2]	**Gene conservation considerations**
plains cottonwood *Populus deltoides* ssp. *monilifera*	S3	G5T5	Plains cottonwood is found only in the Dry Mixedgrass and Mixedgrass Natural Subregions, and is uncommon in both. A prolific seed and clonal reproducer, habitat is restricted to riparian areas. Some poplar populations have been impacted by drought and development. It easily hybridizes with other poplars (see narrowleaf cottonwood). It is a not managed timber species, and is not at risk.
Rocky Mountain Douglas-fir *Pseudotsuga menziesii* var. *glauca*	S5	G5	Rocky Mountain Douglas-fir occurs in four Natural Subregions, although it is uncommon in all but the Montane Subregion, where it is occasional. It is wildfire-adapted, moderately shade-intolerant, and typically occupies warmer, drier sites than associated species. The species exhibits clinal variation driven primarily by growing season moisture and frost free period, associated with elevation and continentality. It is not currently a managed timber species in Alberta although it is a major timber species in the rest of its range. It is not at risk.
Rocky Mountain juniper *Juniperus scopulorum*	S3	G5	Rocky Mountain juniper is uncommon, found primarily in southwest Alberta in the Montane and Subalpine Natural Subregions but also with small populations in coulees and river valleys in the Dry Mixedgrass subregion of southeast Alberta. It is more extensive in adjacent jurisdictions. Typically it grows on dry, open slopes, often with Douglas-fir and limber pine. Juniper is not a managed timber species in Alberta, and it is not at risk.
Scouler's willow *Salix scouleriana*	S5	G5	Scouler's willow occurs as an uncommon tree in five Natural Subregions. Its habitat is upland and adjacent riparian areas. No Alberta sympatric hybrids are reported (Argus 2007). It is not a managed timber species, and is not at risk.

Common name *Scientific name*	**SRANK**[1]	**GRANK**[2]	**Gene conservation considerations**
subalpine fir *Abies lasiocarpa*	S5	G5	The species is common in the Montane subregion, common to abundant in its core distribution across the Subalpine Natural Subregion and a prolific reproducer. It is occasional to uncommon, in six subregions including disjunct populations in the Porcupine Hills. It occurs most frequently on cool, humid sites as a co-dominant with Engelmann spruce. Subalpine fir is not a managed timber species in Alberta, and it is not at risk.
subalpine larch *Larix lyallii*	S4	G4G5	Subalpine larch is uncommon but present in the Alpine and Subalpine Natural Subregions, and is a high elevation species of rocky or gravely sites, often forming pure stands near the treeline. It is expected to decrease with climate change due to hydrological changes in high elevation sites affecting habitat suitability for persistence and recruitment. It is peripheral in AB, and nearly its entire range is within protected areas. Subalpine larch is not a managed timber species in Alberta.
tamarack *Larix laricina*	S5	G5	Tamarack is distributed across 13 Natural Subregions and it is common in several. It is usually found on poorly drained soils, often with black spruce, or occasionally in pure stands. Range-wide studies have shown clinal variation with no unique ecotypes (Johnston et al. 1990). Tamarack is not a managed timber species in Alberta, and it is not at risk.
water birch *Betula occidentalis*	S4	G5	Water birch is uncommon in 10 Natural Subregions, and occasional in the Dry Mixedgrass with disjunct populations in southeastern Alberta. Water birch occurs along river and stream banks, lakeshores, and in wet swales where it forms pure or mixed thickets. Water birch is not a managed timber species in Alberta, and it is not at risk.

Common name *Scientific name*	SRANK[1]	GRANK[2]	Gene conservation considerations
western hemlock *Tsuga heterophylla*	S1	G5	Western hemlock is rare in Alberta and at the eastern edge of its range. Occurrences are tracked in ACIMS[4]. It is found in disjunct populations in the Montane Natural Subregion within Jasper and Banff National Parks. At least one population may be naturalized. It is shade tolerant and most often found in dense, moist forest with other conifer species. It is considered likely to be extirpated in situ in Alberta within 100 years due to climate change. It is not a managed timber species in Alberta.
western larch *Larix occidentalis*	S2	G5	Western larch occurs in the Montane and Subalpine Natural Subregions and is rare in Alberta. Occurrences are tracked in ACIMS[4]. It is at the northeast margin of its range, growing in mixed stands with Rocky Mountain Douglas-fir. Small populations occur in Waterton Lakes and Banff National Parks, and a larger population occurs in the Crowsnest Pass area. Western larch is not a managed timber species in Alberta, and its range in Alberta is expected to decrease with climate change as projected changes in moisture will affect habitat suitability.
western redcedar *Thuja plicata*	S2	G5	Western redcedar is rare in Alberta with disjunct easternmost populations in two Natural Subregions, mostly in the Rocky Mountain national parks and scattered in adjacent moist montane forests. Occurrences are tracked in ACIMS[4]. Alberta populations occur in marginal habitats and may be at risk due to drought. It is not a managed timber species.
western white pine *Pinus monticola*	S2	G4G5	Western white pine is rare and restricted to a few outlying occurrences at its climatic limits in the Crowsnest Pass region in Alberta, where it is usually found on rocky slopes or ridge tops, often with limber pine or Douglas-fir. Occurrences are tracked in ACIMS[4]. It has however a more contiguous range west and south, where there are successful operational tree improvement programs for white pine blister rust resistance. It is not a managed timber species.

Common name *Scientific name*	SRANK[1]	GRANK[2]	Gene conservation considerations
western yew *Taxus brevifolia*	S1	G4G5	This species reaches its eastern range limit in Alberta and is likely to be extirpated in situ in Alberta within 100 years due to climate change. Occurrences are tracked in ACIMS[4]. There is only one location record in Alberta, found in a moist stand of mixed conifers in Waterton Lakes National Park. The population may have been extirpated by wildfire in 2017. It is not a managed timber species.
white spruce *Picea glauca*	S5	G5	White spruce is the most commercially important and widespread tree species in Alberta with extensive tree improvement programs. It is found in 15 subregions and common to abundant in eight, including an isolated population in the Cypress Hills and scattered stands on north-facing slopes in the Central Parkland. Hybrids between Engelmann and white spruce are common.
whitebark pine *Pinus albicaulis*	S3	G3G4	Whitebark pine, listed as an endangered species under the *Species at Risk Act* and the *Alberta Wildlife Act*, grows in the Alpine and Subalpine Natural Subregions. This species is tracked by ACIMS[4]. It is a high elevation tree typically on exposed southern slopes and rocky ridges. Populations are rapidly declining due to white pine blister rust and mountain pine beetle. Mortality and infection approaches 100% in the southwest, declining around Highway 1, increasing further north. Wildland fire suppression and climate change are also threats. It is not a managed timber species, although there is incidental harvest with lodgepole pine.

[1]SRANK: subnational (Alberta) ranking. **S1**: ≤5 occurrences, or especially vulnerable to extirpation due to other factor(s); **S2**: ≤20 occurrences or vulnerable to extirpation due to other factors; **S3**: ≤100 occurrences, or somewhat vulnerable due to other factors (e.g. restricted range, relatively small population sizes); **S4**: apparently secure, uncommon but not rare, potentially some cause for long term concern due to declines or other factors; **S5**: secure - taxon is common, widespread, and abundant; **SU**: Taxon is currently unrankable due to lack of information or substantially conflicting information, e.g. native versus non-native status not resolved; **S#S#**: range rank is used to indicate uncertainty about the status of the taxon; **S#?** applied when a specific rank is most likely appropriate but for which some conflicting information or unresolved questions remain, e.g. S2? believed to be 6 - 20 occurrences but some uncertainty.

[2]GRANK: global (NatureServe) ranking (ACIMS October 2015): numbers are the same as SRanks; T indicates a subspecies or variety.

[3] Committee on the Status of Endangered Wildlife in Canada, federal advisory body on Species at Risk

4 Alberta Conservation Information Management System, database tracking species and ecosystems

5.3 Gap analysis strategy

The following process was followed to identify gaps in the adequacy of existing species/natural subregion in situ conservation sites:

- Species' range maps were overlain with protected areas. For minor species' ranges, expert advice, field records, and/or habitat modelling was necessary as spatial inventory to generate reliable range maps was often limited or inaccurate.
- Adequacy of existing conservation sites was determined, considering size of area, number and security of reserves based on known occurrences, density, disturbance, and other relevant factors.
- Gaps were identified in the existing network of formal in situ conservation sites.

In most cases adequacy of protection is assessed based on estimated density and genetic diversity distribution for populations of the target species, with the objective of capturing 5,000 mature individuals in a contiguous area. Not all trees reproduce each year, and trees contribute different amounts of seed and pollen to the next generation. The number of individuals actually contributing genes to the next generation, based on calculations adjusting for these factors, is called effective population size. Most conifers have mechanisms to minimize inbreeding so a census population of 5,000 corresponds with an effective population size of 1,000, sufficient for long term maintenance of rare alleles (Yanchuk 2001). For species with: frequent vegetative reproduction, high inbreeding or mating among related individuals, continuous or disjunct distribution margins extending into Alberta, small populations, or limited gene flow, it may not be possible to meet this objective so the threshold for adequacy may need to be adjusted.

The following strategy is recommended to move towards filling the gaps in in situ conservation sites:

- Locate candidate areas, protect multiple species in a single site wherever possible.
- Prioritize candidate sites by first considering land excluded from the harvesting landbase such as protected areas, candidate protected areas with Crown land dispositions, existing buffers, inoperable areas, and non-merchantable stands on Crown lands.
- Confirm inventory of the target species in the priority candidate areas by field verification.
- Fill remaining gaps by selecting additional candidate sites from the list above and confirm the presence of the target species by field verification.
- Formalize gene conservation areas by establishing protected areas or land dispositions for gene conservation or working with other agencies or groups to align land use direction and priorities to secure either voluntary or formal protection of populations.
- If dispositions cannot be established at all target sites, the gene conservation status will still be assessed based on demographics and distribution (i.e., if abundant and widespread but not adequately represented within protected areas or conservation dispositions, status may still be considered secure).
- Monitor every 10 to 20 years to ascertain if the area is still meeting the objective, if it is still needed, or if it needs to be substituted with another area or more actively managed.

Ex situ approaches complement and supplement in situ reserves. A separate ex situ conservation plan exists to address the role of operational and conservation seed, linkage to the in situ program, special conservation needs and implementation through provincial forest genetics standards.

A screening approach is outlined below that evaluates each species in each natural subregion in which it occurs. Table 2 summarizes species distribution and abundance by natural subregion. Each species/subregion combination is assigned to one of three groups (Figure 3) and based on the assigned group, a decision tree (Figure 4) is then used to set priorities. In Figures 4A, B, and C, the top priority for conservation action is P1 and the lowest priority is P5. Priority assessment uses criteria such as whether there is a tree improvement program in Alberta, and distribution patterns (e.g., clumped vs. scattered on the landscape). Unique factors to consider include outliers, areas with known unusual genes, environmental extremes, and areas with disturbance threats. Details of factors considered are summarized for each species in Table 3 and detailed in Appendix 1.

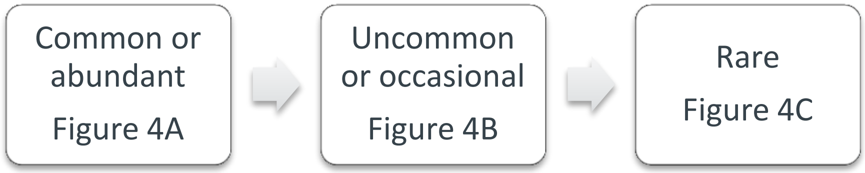

Figure 3. Decision path for assessing species-natural subregion combinations.

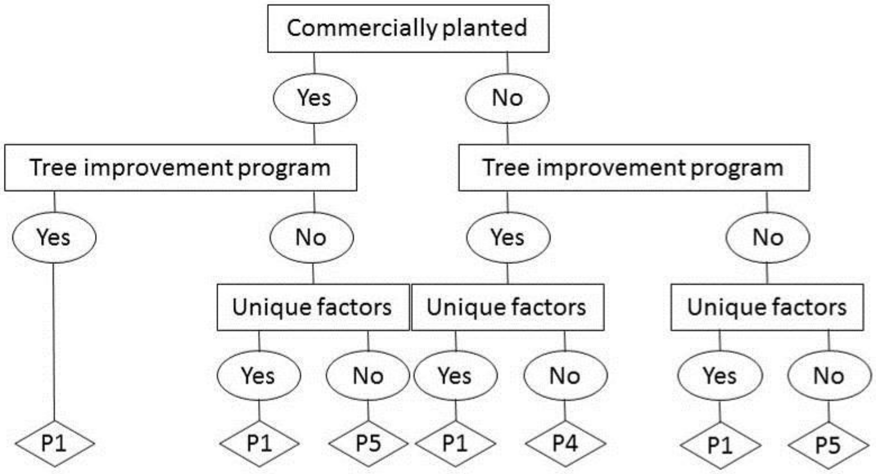

Figure 4A. Decision path for determining conservation priorities of common or abundant species. P1 is top priority, P5 is lowest priority.

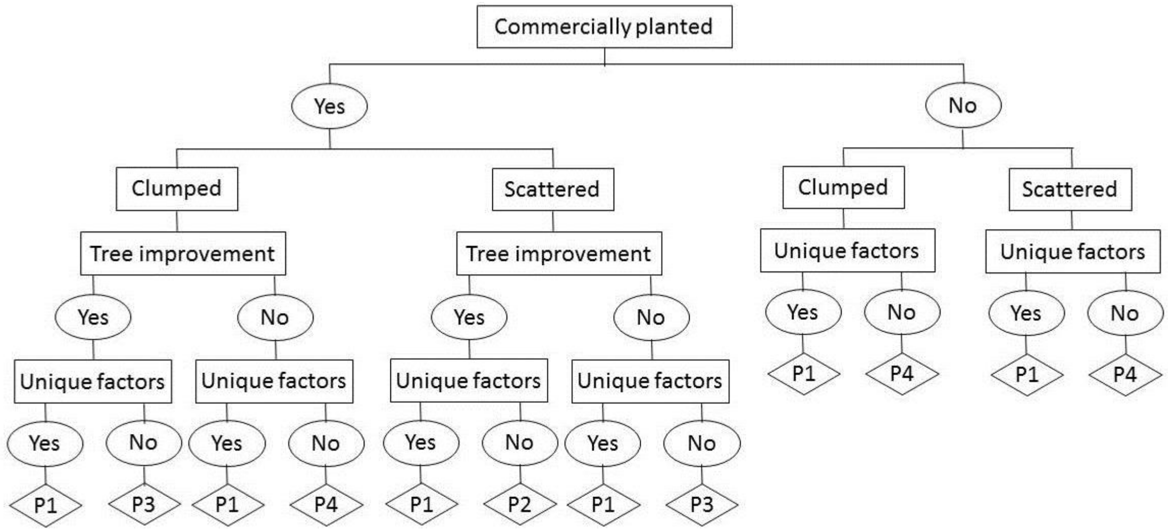

Figure 4B. Decision path for determining conservation priorities of clumped or scattered species. P1 is top priority, P5 is lowest priority.

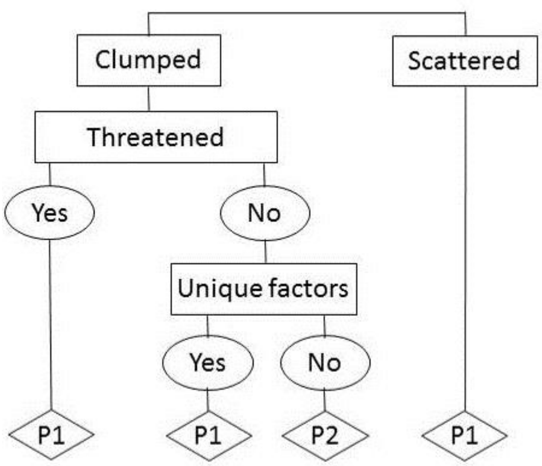

Figure 4C. Decision path for determining conservation priorities of rare species. P1 is top priority, P5 is lowest priority.

5.4 Gap analysis results

Table 4. Species requiring no further in situ gene conservation reserves due to conservation status or peripheral distributions.

Species	Rationale
black cottonwood	• most Alberta occurrences are within protected areas • well protected in the rest of its distribution • high reproductive capacity
green ash	• widely naturalized • native populations not easily identified
Manitoba maple	• widely naturalized • native populations not easily identified
western white pine	• a few disjunct marginal populations in SW Alberta • species is well protected elsewhere • likely to be extirpated in Alberta within 100 years due to climate change

Table 5. Species/natural subregion combinations identified as requiring no additional in situ gene conservation action due to commonness, abundance, or secure populations

Species	Rationale
Alaska birch	• widespread with habitat that is generally excluded from the managed forest land base and is not a target of harvesting • populations are considered intact and not at risk • well represented in protected areas
aspen	• most abundant tree in Alberta • cooperators in approved tree improvement Controlled Parentage Programs are working to establish gene conservation areas • abundant in protected areas
balsam fir	• broadly distributed and not a desirable timber species • adequately represented in protected areas across all natural subregions identified in Table 2
balsam poplar	• common and widespread • balsam poplar and its hybrids all prefer moist and riparian habitats and it can be considered well protected informally in streamside buffers • large populations are excluded from harvest in unmerchantable stands • widespread outside the harvesting landbase • well represented in protected areas

Species	Rationale
black spruce	• broadly distributed in poorly drained forests, • studies have shown clinal variation with no unique ecotypes • a relatively infrequent harvest target in Alberta • stands are frequently excluded from harvest due to sensitive soils, poor drainage, and relatively low value • well represented in protected areas • informally very well represented across the unprotected landbase • cooperators in approved tree improvement Controlled Parentage Programs are working to establish gene conservation areas in applicable locations
Engelmann spruce	• common and abundant in the Rocky Mountain Natural Region • extensively protected in national and provincial parks
jack pine	• extensive populations grow on suitable sites • includes an broad hybrid zone with lodgepole pine across most of its Alberta range • harvested, but there are extensive areas of informally retained non-merchantable stands • well represented in protected areas • cooperators in approved tree improvement Controlled Parentage Programs are working to establish gene conservation areas in applicable locations
lodgepole pine	• extensive populations grow on suitable sites • can regenerate in extremely dense stands, and hybridizes with jack pine where they overlap • a major timber species in Alberta • cooperators in approved tree improvement Controlled Parentage Programs are working to establish gene conservation areas in applicable locations • well represented in protected areas including disjunct genetically unique Cypress Hills population • serotinous cones support a prolific, long-lived seed bank in situ
paper birch	• broadly distributed • harvested incidentally with other broadleaf species • well represented across the protected areas network except in Peace River Parkland and Foothills Parkland • hybridizes with other birches where they are sympatric, so birch inventory records from the Peace River Parkland and Foothills Parkland Natural Subregions may be dominated by related species or hybrids • found in buffers, shelterbelts, natural remnants, and woodlands in the rest of the informally retained land base • southern part of the range may become climatically unsuitable for paper birch in the next century regardless of its genotype due to climate change
plains cottonwood	• extends through southeast Alberta • not a timber species and does not occur in the operational forestry region of Alberta • detailed range and inventory data is lacking • appears secure in Alberta based on protected areas distribution and land use

Species	Rationale
Rocky Mountain Douglas-fir	• relatively extensive range throughout Montane and some adjacent Natural Subregions • well represented in protected areas • special reserves specifically for Rocky Mountain Douglas-fir genetic and ecosystem conservation have been established • predicted to increase in abundance and expand its Alberta range with climate change
Rocky Mountain juniper	• scattered but widespread on suitable xeric sites • not a merchantable species • well represented within protected areas
subalpine fir	• common and widespread across its range in Alberta • a prolific reproducer • not regarded as a merchantable species, often retained in forestry • well protected in the national and provincial protected areas network
tamarack	• common within its range across northern Alberta • studies have shown clinal variation with no unique ecotypes • not a target species for harvest in Alberta • stands are frequently excluded from harvest due to sensitive soils, poor drainage, and low value • well represented in the protected areas network
white spruce	• one of the most common and abundant species in Alberta • commercially managed timber species • well represented in protected areas, including the disjunct and genetically unique population in Cypress Hills • widespread in buffers and areas excluded from the harvesting land base • cooperators in approved tree improvement Controlled Parentage Programs are working to establish gene conservation areas in applicable locations

Table 6. Species/natural subregion combinations requiring gene conservation action: population verification, additional protection

Species	Rationale	Recommended action
Priority 1: rare, scattered		
subalpine larch	• peripheral Alberta range • almost entirely within protected areas in Alberta and moderately well protected in B.C. • likely to be extirpated in Alberta within 100 years due to climate change	• work with parks agencies to document occurrences • improve Alberta inventory in ACIMS
western hemlock	• peripheral Alberta range, entirely within protected areas • likely to be extirpated in Alberta within 100 years due to climate change	• work with parks agencies to ensure documented populations are identified and managed
western larch	• rare in Alberta • at the eastern and climatically continental limit of its range • bioclimatic envelope models indicate it will retain a marginal presence in Alberta or be extirpated in the coming decades • populations, likely with fewer than 5,000 mature trees, are represented in Waterton Lakes National Park and Castle Wildland Provincial Park; C5 Forest Management Unit contains thousands • reserved from harvest on Crown land in Alberta.	• confirmation of population size in protected areas is recommended • based on results, determine whether more gene conservation reserves are required • explore assisted migration options
western yew	• peripheral Alberta range • Alberta range entirely within protected area • likely to be extirpated in Alberta within 100 years due to climate change • may have been extirpated by 2017 Kenow Mountain wildfire	• field survey to verify status of Alberta populations post-fire
Priority 1: unique considerations		
whitebark pine	• undergoing rapid decline • low fecundity and persistent threats make gene conservation challenging	• passive in situ conservation is inadequate to mitigate or reverse threats to the species • active restoration with genetically diverse disease resistant seedlings is necessary in areas with moderate to high levels of white pine blister rust • creation of suitable regeneration sites required to sustain populations in situ

Species	Rationale	Recommended action
limber pine	• undergoing rapid decline • low fecundity and persistent threats make gene conservation challenging	• passive in situ conservation is inadequate to mitigate or reverse threats to the species • active restoration with genetically diverse disease resistant seedlings is necessary in areas with moderate to high levels of white pine blister rust • creation of suitable regeneration sites required to sustain populations in situ
Priority 5: not rare, not commercially planted, no tree improvement, no unique factors		
chokecherry	• widely distributed • likely adequately represented in protected areas, but detailed data are lacking	• surveys to confirm presence and abundance are recommended
narrowleaf cottonwood	• occurs in a few scattered populations in southern Alberta • no population genetic data or accurate range map are available • clonal growth habit indicates larger reserves are required to meet the diversity target or a literature review may indicate if the target should be reduced	• field surveys to confirm presence and abundance are recommended • literature review on genetic diversity patterns to guide reserve selection
peachleaf willow	• restricted to moist sites in southeast Grasslands Natural Region • at the northern limits of its range • detailed range and inventory data are lacking	• field surveys to confirm presence and abundance are recommended
pin cherry	• very broadly distributed • likely adequately represented in protected areas, but detailed data are lacking	• field surveys to confirm presence and abundance are recommended
Scouler's willow	• common and widely distributed • unlikely to have any conservation gaps, but detailed range and inventory data are lacking	• field surveys to confirm presence and abundance are recommended
water birch	• a widespread non-merchantable species • this species and its hybrids are adequately represented in areas excluded from the harvesting landbase and in protected areas in western and southern Alberta	• gene conservation reserves for populations of this species may be warranted in the Central Parkland, Dry Mixedgrass, Mixedgrass, and Northern Fescue Natural Subregions

6 Implementation, Monitoring and Reporting

An established gene conservation reserve should meet the objective for 100 years or more with periodic reviews (10 to 20 years) of the status of conservation and any changes that may be needed in management or delineation of the area to fulfill its objectives. The main changes that may impact species distribution and allele frequencies in a specific site are disturbance, succession, trespass, and climate change and/or development (e.g. a dam or weir altering riparian water levels) rendering the habitat unsuitable.

Management and monitoring to establish and evaluate gene conservation sites should include:

- A baseline population inventory upon establishment to confirm number and condition of the target species – consider seed collections if convenient to supplement ex situ gene conservation if a gap is identified for the species-Natural Subregion combination.
- Remote sensing and GIS assessment every ten years for forest health issues, wildfire, or development applications or to determine if a boundary change may be needed as a result of disturbances.
- Monitoring site visit every 10 to 20 years to quantify population census and condition, and assess the need to continue, move, realign, or discontinue the reserve.
- For species with special factors or active in situ recommendations, reporting and activities consistent with recovery plans.
- Reporting on status and trends (for reserves established under FGRMS the assessments and monitoring schedule may vary as per approved plan).

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Appendix 1. Descriptions of Native Alberta Tree Species

Alaska Birch (*Betula neoalaskana* Sarg.) Betulaceae


A.J. Gould L. Allen

Species Characteristics Alaska birch is a small to medium-size tree reaching 15 metre tall and 20 centimetre in trunk diameter. The young bark is smooth and reddish-brown with the transverse lenticels characteristic of birch. In mature trees the bark is white and peels off in layers. The thin, triangular to broadly oval leaves are four to seven centimetres long with twice-serrate margins, tapering at the tip and lacking hairs in the vein axils. The hairless twigs are densely warty-glandular. Male and female flowers are produced in catkins on the same tree, the latter on short spur shoots. A similar species is paper birch (*B. papyrifera*), which has hairy twigs, more ovate leaves and the leaves have hairs in the vein axils. Their ranges overlap and the two hybridize.

General Ecology A northwestern boreal species adapted to cold climates, Alaska birch grows in mixed bogs and less commonly in upland forests and ranges from northwestern Ontario across the prairie provinces and territories of Canada into Alaska. In Alberta, this species is concentrated mostly in the north central region, extending into the far northeast. It is apparently absent from the foothills and mountains and the far northwest. No detailed range map is available.

Alaska birch occurs in bogs and on poorly drained mineral soils, as well as on sand hills and in open woods, as pure stands or in mixtures of other species, often with black spruce (*Picea mariana*), white spruce (*P. glauca*), balsam fir (*Abies balsamea*) and aspen (*Populus tremuloides*). It is fast-growing as befits a seral species but it is also short-lived, rarely exceeding 150 years (Klinka et al. 2000). Fallen birch leaves decay quickly, enriching the soil.

Regeneration Reproduction of Alaska birch is mainly by seed. Wind-pollination occurs in the early spring and the small winged samaras mature in fruiting catkins, which gradually become pendant in the fall. Fruits are dispersed gradually over the course of the winter and often are blown long distances over glazed snow. Alaska birch reaches full fruit production by the age of about 15 years and birch stands produce abundant seed crops every year. Exposure to light is necessary for the germination of seeds. Vegetative reproduction also takes place by the sprouting of stumps. The species regenerates early after logging or fire but, being shade-intolerant, it is out-competed by other species after a few decades.

Evolution and Genetics The birches are taxonomically complex in North America with up to 16 recognized species and two subspecies, and many varieties and hybrids that are not really possible to accurately distinguish based on morphology (Furlow 1997; Schenk et al. 2008). Alaska birch is diploid, while paper birch is hexaploid (Furlow 1997). It closest affinities are to the Asian members of a circumpolar complex. Alberta has six native species but only Alaska, white and water birch (*B. occidentalis*) are classified as trees. Natural hybrids of Alaska birch with white and water birch, as well as with dwarf birch (*B. glandulosa*), have been reported, and zones containing hybrid swarms of varying degrees of introgression are common (Schenk et al. 2008).

Stevens et al. (2016) found strong relationships between morphological traits, defense mechanisms and latitude that were also associated with disturbance regimes (fire frequency and extent). Populations originating from further north had more resin glands, more resources allocated to roots and less to shoots, and smaller leaves.

This species is well represented in protected areas, including Wood Buffalo National Park; Birch River, Caribou Mountains, Chinchaga, Colin-Cornwall Lakes, Dunvegan West, Hay Zama, La Biche River, La Butte Creek, Marguerite River, and Peace River Wildland Provincial Parks; Cold Lake and Lakeland Provincial Parks; and likely others. No conservation gaps are identified. All natural subregions where it occurs have abundant predicted distribution of this species within parks. Its habitat is generally excluded from the managed forest land base and is not a target of harvesting. Other habitat impacts, mostly in northeast and east-central Alberta are primarily due to mining, but populations are considered intact and not at risk.

Aspen (*Populus tremuloides* Michx.) Salicaceae

A.J. Gould

L. Allen

Species Characteristics Aspen is a medium-sized short-lived tree. The smooth grey-green to beige bark has black patches and scars covered in white powder, becoming furrowed with age. Leaves are dark green above, pale green below, turning yellow (sometimes orange or red) in autumn before shedding. Leaves are nearly round with a sharply-pointed tip, a toothed margin, flattened petiole as long as the leaf blade, and three prominent midveins. Pollen and seeds are produced on different trees in many-flowered catkins. Seedshave long white hairs attached and disperse by wind long distances in wind during spring. Balsam poplar (*P. balsamifera*) has an overlapping range in much of Alberta. The ranges of plains cottonwood (*P. deltoides* ssp. *monilifera*) and narrowleaf cottonwood (*P. angustifolia*) overlap aspen in southern Alberta.

General Ecology Aspen is the most widely distributed tree in North America, from Alaska to Newfoundland into Mexico. The species is found in much of Alberta, becoming scattered in the southeast is. In the Central Parkland Natural Subregion, aspen is the dominant tree species and commonly grows in stunted clonal stands surrounded by grasslands. In low elevation forests of the foothills and boreal regions, aspen is the dominant early-successional species with a lesser component of balsam poplar and paper birch (*Betula papyrifera*); occasionally with Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) in the montane. As succession progresses, aspen is replaced by shade-tolerant conifers such as white spruce (*Picea glauca*), black spruce (*Picea mariana*), and balsam fir (*Abies balsamea*).

Young aspen stands provide habitat and food for many species of animals, birds, insects, and fungi. Aspen stands also serve as natural firebreaks. Recent studies indicate climate change is driving severe droughts that are impacting the persistence of numerous aspen stands and leading to a northward shift of the southern range limit of the species (Michaelian et al. 2011).

Regeneration Seed production in aspen is common, and seeds can be dispersed long distances. Seed has a short period of viability, and has a limited range of site requirements for successful seedling establishment. Although individual stems typically short-lived, clones may live for centuries.

The maintenance of aspen as a forest component is mainly by root suckers. These sprouts develop from buried meristems in root systems and result in a somewhat dome-shaped group of stems that share an interconnected root network. Where these stems arise from a single tree, individuals are considered as one clone with the same genes, although studies have measured mutations within clonal stands, and also between related seedlings growing at the margins of clones, adding to the diversity of stands (Namroud et al. 2006; Gardner 2013).

When apical dominance is released after mature stems or root systems are damaged, abundant root suckers emerge. Aspen is widely harvested for pulp. Regeneration is typically from the sprouts. Although nursery culture of aspen from seed and root sections is feasible, the ease of regeneration from sprouts deters planting. Aspen grows very rapidly with adequate nutrients and moisture.

Evolution and Genetic Variation Taxonomy of the genus *Populus* has undergone substantial revision with the use of genomic tools. Natural hybrids between aspen and other native poplars in Alberta have been reported based on morphology (Brayshaw 1966), but never confirmed by genotyping. Artificial hybrids of aspen with other species of poplar native to Alberta and introduced from Europe and Asia have been produced.

Genetic variation associated with geography reflects both adaptation to broad and some local environmental gradients, and patterns of postglacial colonization. Gender differences related to environmental gradients have also been demonstrated with the proportion of males increasing with elevation and in harsher environments (as in many other dioecious species). Testing of Alberta populations for tree improvement has been ongoing and propagation and deployment of improved aspen is feasible. Aspen is the most abundant tree in Alberta, found in pure and mixed stands with white spruce and jack and lodgepole pines. Companies with approved tree improvement Controlled Parentage Programs are working to establish gene conservation areas. A prolific and early clonal reproducer, but also exhibiting high diversity and frequent sexual reproduction, aspen recolonizes sites from root sprouts after disturbance. Clonal species would need far more than 5,000 stems to retain the benchmark number of genotypes, but mature stands of poplar are dense and abundant. Poplar species are often grouped together in inventories, and ABMI distribution models indicate it is abundant in protected areas, except in the driest grasslands natural subregions, although it is likely adequately conserved there as well. It is safe to say that aspen is not in need of additional conservation measures and it is abundant in reserves where it is present. Hogg et al. (2002) have noted extensive and increasing aspen dieback throughout the aspen parkland, likely exacerbated by increasing drought (Chen et al. 2017) attributed to climate change (Michaelian et al. 2011). In situ conservation would not offset or reverse this effect. No conservation gaps are identified.

Balsam Fir (*Abies balsamea* (L.) Mill.) Pinaceae

M. Mochulski L. Allen

Species Characteristics Balsam fir is a medium-sized tree with a maximum age of about 200 years. On young trees, the bark contains numerous resin blisters; on older trees, bark is scaly. Leaves have blunt or minutely notched tips and are arranged in two ranks, shiny green above and whitish below. Seed and pollen cones are borne on the same tree. Seed cones are five to ten centimetres long and upright. Cone scales dehisce at maturity leaving the central axis attached to the branch.

General Ecology Balsam fir is distributed from Labrador to the Peace River Valley in Alberta but is not found as far north as its common associate, white spruce (*Picea glauca*). The species grows from sea level in the northeast to nearly 2,000 metres in scattered populations on mountains along its southern boundary in West Virginia. Fullest development is achieved in the northeastern United States and southeastern Canada where it is a major component of several forest types and a minor component of many more. In the western part of the species range, populations become more scattered and restricted to stream valleys and north-facing slopes. In Alberta, balsam fir is found mainly in in northeast and east-central Alberta in the boreal forest and in suitable sites in the foothills. It occurs in pure stands and in combination with white spruce, black spruce (*Picea mariana*), paper birch (*Betula papyrifera*) and aspen (*Populus tremuloides*). It is found on neutral to acidic soils ranging in texture from clay loams to gravelly sands with adequate moisture.

The species has a scattered distribution in Alberta throughout lower to mid elevations in northern boreal forests, extending southward along the foothills at lower elevations to the area around Rocky Mountain House. In the Foothills Natural Region, identification becomes problematic due to hybridization with Rocky Mountain alpine fir (*A. lasiocarpa*) at mid to higher elevations.

Locating peripheral and disjunct stands is also challenging due to balsam fir being a shade tolerant, climax species in ecosystems with short fire return intervals, where most trees grow below the main canopy in early to mid-successional stands. The high resin content in leaves and bark can make balsam fir highly flammable; with shallow roots and thin bark, the trees are easily killed by fire. Some peripheral and outlier populations likely occur in older stands on moister sites in the Dry Mixedwood Subregion of the Boreal Forest Natural Region but inventory of this non-commercial species is limited.

Regeneration Balsam fir reproduces almost entirely by seed although lower branches may develop roots when in contact with moist soil. Seed production begins at about age 15 and substantial seed production often follows a two year cycle. Seed dispersal is mainly by wind.

Seedling establishment is most successful under shade and early growth is rapid even in dense shade. Balsam fir is classified as very tolerant of low light and will live for many years in dense shade, but grows rapidly when released. It is considered a late-successional species.

Evolution and Genetics Balsam fir is one of ten or 11 species of *Abies* native to North America, varying with the taxonomic reference. The number of species recognized varies by taxonomic authority. For Alberta, opinions range from regarding all native *Abies* species as variants of balsam fir to granting species status to the taxon distributed in the western part of the province as either subalpine fir (*A. lasiocarpa*), (*A. balsamea ssp*. *lasiocarpa*) or Rocky Mountain subalpine fir (*A. bifolia*). Trees in many locations have characteristics intermediate between balsam fir and subalpine fir, which suggests hybridization occurs where they grow together (Frank 1990), but no genotypic confirmation has been done. This report treats populations from higher elevations in western Alberta as subalpine fir and hybrids in areas where the distribution of balsam fir overlaps it.

Studies of genetic variation among populations have shown typical patterns of gradual change over geographic and elevational distances (Lester et al. 1976; Lowe et al. 1977), with fairly low total genetic diversity but higher chloroplast marker diversity, and more tolerance of inbreeding relative to other conifer species (Clark et al. 2000; Shea and Furnier 2002). Disjunct populations drive most of the population genetic differences. Spring frost injury is an especially important problem in balsam fir. Transfer of seed from north to south has often resulted in spring frost injury because northern sources burst buds before the risk of frost is over, similar to findings in other tree species.

There is no tree breeding with balsam fir in Alberta. Genetic variation is being utilized elsewhere, mainly for the production of Christmas trees with improved leaf color and later bud opening to avoid late-spring frost. No conservation gaps are identified; however, provincial range-wide modelling data from ABMI appears to reflect areas that include primarily or wholly subalpine fir.

Balsam Poplar (*Populus balsamifera* L.) Salicaceae

C. Crell

L. Allen

Species Characteristics Balsam poplar is a large tree with grey, deeply furrowed bark and yellow-orange twigs. Individual stems may live for 200 years and root sprouts can perpetuate the same genotype for many more years. Leaves are roughly oval, with a shiny, bright-green upper surface and paler surface below. Slightly toothed or smooth leaf margins converge at a sharply-pointed tip. Petioles are rounded. The large, resinous buds are distinctively aromatic. Pollen and seeds are produced on different trees in long catkins and seeds have long white hairs that facilitate seed transport by wind. Aspen (*P. tremuloides*) is a related species with an overlapping range in much of Alberta. Plains cottonwood (*P. deltoides* ssp. *monilifera*) and narrowleaf cottonwood (*P. angustifolia*) have ranges that overlap balsam poplar in southern Alberta. Where they overlap, this species hybridizes with black cottonwood (*P. trichocarpa*).

General Ecology Balsam poplar is found from Newfoundland to Alaska in mostly interior and continental habitats. The principal range extends from the northern limit of trees south to about 35°N in eastern North America. The distribution then continues northwesterly with a southern boundary at about 60°N in Alaska. Scattered populations, however, are common along the southern edge and extend as far south as Colorado. In Alberta, scattered populations occur in the southwestern part of the province and the main distribution follows the northern edge of the Central Parkland Natural Subregion. Balsam poplar is an early-successional species and is very intolerant of shade.

Balsam poplar often grows on floodplains, along riverbanks and in areas that have periodically wet soils. On wetter sites, balsam poplar may be found in association with various willow species. On upland sites, associates can be balsam fir (*Abies balsamea*), black spruce (*Picea mariana*) and white spruce (*P. glauca*), aspen, and paper birch (*Betula papyrifera*).

Regeneration Balsam poplar is versatile in its reproduction. The minimum age for seed production is eight to ten years. Older trees produce large quantities of seed. Seeds are dispersed by wind and water. The seeds have a short period of viability, and wet mineral soils are optimal for successful seedling establishment.

Balsam poplar can also regenerate from shoots sprouting from roots and stumps. Regeneration from root sprouts is common but less prolific than for aspen. Regeneration also occurs less frequently from branch tips and branches that break off. Early growth is usually rapid. Root development along the buried stem can accommodate soil deposited by flooding, forming a multi-layered root system.

Evolution and Genetic Variation Studies have quantified genetic variation in a large suite of adaptive traits from cold hardiness to resistance to various insects and pathogens to seed traits and fibre properties. There have been numerous genomic studies done as well, although technical challenges have arisen due to the species' tetraploidy. A tree improvement program was initiated in eastern Alberta but was discontinued for business reasons. Breeding programs exist in other provinces for enhanced fibre yield.

This species is common and widespread from the Pacific to the Atlantic, across all northern forests, with scattered populations south to Colorado. No accurate range map for Alberta is available as it is generally classified as *Populus* sp. in inventories. Balsam poplar and its hybrids all prefer moist and riparian habitats. Its ability to reproduce vegetatively and sexually warrants a larger sample to capture 5,000 unrelated genotypes; however, it can be considered well protected in streamside buffers and through its presence in areas outside the harvesting landbase, in addition to its presence in protected areas with riparian areas. Even where it is managed for pulp production, large populations of balsam poplar are excluded from harvest in unmerchantable stands. ABMI modelling data indicates it is very well protected, and even in the driest grasslands natural subregions it likely is more abundant than distribution models predict based on observation.

Black cottonwood (*Populus trichocarpa* Torr. & Gray) Salicaceae

Blake C. WIlson, http://TreeLib.ca

Species Characteristics Black cottonwood is a large tree that typically has a single, straight trunk expanding upwards into a single rounded canopy. Mature trees have grey, deeply furrowed bark and twigs have long, pointed, aromatic, resinous buds. Individual stems may live for 400 years but most commonly 100 to 200. Root sprouts perpetuate the same genotype for many more years. Leaves are roughly oval, with a shiny, bright-green upper surface and paler surface below. Slightly toothed or smooth leaf margins converge at a sharply-pointed tip. Petioles are rounded. Pollen and seeds are produced on different trees in long catkins and seeds have long white hairs that facilitate seed transport by wind. Balsam poplar (*P. balsamifera*) is a closely related species with an overlapping range that hybridizes where they grow together, but has a much more extensive range throughout Alberta.

General Ecology Black cottonwood is a primarily coastal species, only extending a limited way into southwest Alberta in river valleys in the Montane Natural Subregion. Its range extends from

Alaska to western Mexico, with peripheral populations as scattered islands while the core population is contiguous. Black cottonwood is an early-successional species and is very intolerant of shade.

Black cottonwood often grows on floodplains, along riverbanks and in areas that have periodically wet or flooded soils. On wetter sites, it is associated with various willow species. On upland sites in Alberta, associates can include white spruce (*Picea glauca*) and paper birch (*Betula papyrifera*).

Regeneration Black cottonwood is versatile in its reproduction. The minimum age for seed production is around 10 years and older trees produce large quantities of seed. Seeds, aided by attached cottony tufts, are dispersed by wind and water. Seed has a short period of viability, however, and wet mineral soils are optimal for successful seedling establishment.

Black cottonwood can also regenerate from shoots sprouting from roots and stumps. Regeneration from root sprouts is common but less prolific than for aspen. Regeneration also occurs less frequently from branch tips and branches that break off. Early growth is usually rapid. Root development along the buried stem can accommodate soil deposited by flooding, forming a multi-layered root system.

Evolution and Genetic Variation Studies have quantified genetic variation in a wide range of adaptive traits including growth rates, cold hardiness, drought tolerance, seedling traits, and genotypic diversity, but no data have been collected from Alberta. This species has also been used as a model organism for genomic studies and resulted in a plethora of publications on taxonomy, evolution, and genomic markers.

Black cottonwood is common and widespread from the Pacific to the California coast, with scattered populations extending inland along river valleys to the continental divide. No accurate range map for Alberta is available as it is generally classified as *Populus* sp. in inventories. Black cottonwood and its hybrids all prefer moist and riparian habitats. Its ability to reproduce vegetatively and sexually warrants a larger sample to capture 5,000 unrelated genotypes; however, it can be considered well protected in streamside buffers, and in protected areas with riparian areas.

Black Spruce (*Picea mariana* (Mill.) B.S.P.) Pinaceae

A.J. Gould

J.D. Johnson

Species Characteristics Black spruce is a very narrow-crowned tree, often with a club-shaped top. It can live over 300 years. The blue-green leaves with blunt tips are four-sided and arrayed around twigs that usually are hairy. Seed and pollen cones are produced on each tree. Seed cones are two to three centimetres long, dark brown to purple, with cone scales that have wavy margins. Seed cones are held on trees for many years. Similar species in Alberta are white spruce (*P. glauca*) and Engelmann spruce (*P. engelmannii*).

General Ecology Black spruce is a major component of the Boreal Forest stretching across the continent from the northern limit of tree growth to near 45°N in the eastern portion of its range. In eastern Alberta, the southern limit of the species is Lloydminster, then west to Smoky Lake, southwest to Lake Louise. Unlike white spruce, it has not been found in the river valleys in the Central Parkland Natural Subregion nor in the Cypress Hills.

The species often is associated with saturated organic soils and permafrost although it grows well on soils with better drainage. On wet sites, the most frequently associated tree species is tamarack. In the foothills and highest elevations of boreal hill systems, it is common on upland sites as a component in even-aged stands with lodgepole and jack pine hybrids following fire. On upland sites in the boreal forest, it is less common in mixed stands with white spruce, poplars, and jack pine.

Regeneration Black spruce reproduces naturally by seed and not by layering (Fayle 1996). Good cone production generally begins at about 30 years of age with substantial crops at two to six year intervals. Seed cones are persistent and semi-serotinous so that seed from a given year may be released over a period of many years. Wildfire accelerates the opening of cones and seed release. Many seedling competitors outgrow black spruce and although the species is shade-tolerant, fire can reduce competition and facilitate the establishment of young black spruce forests.

Evolution and Genetic Variation Five spruce species are native to Canada, and three to Alberta, Engelmann spruce, black spruce and white spruce. Hybridization with white spruce does not occur (Nkongolo et al. 2005). No hybrids with Englelmann spruce are reported.

Genetic variation in black spruce has been extensively studied as it is a major commercial forestry species in central and eastern Canada. Genetic diversity is relatively low, with moderate differentiation among populations, even across large regions. There is a limited tree improvement program in Alberta.

Black spruce has a broad boreal to sub-boreal distribution in poorly drained forests, where it is most often found in fairly dense stands with tamarack, balsam poplar, and paper birch, but does occur in pure stands. Range-wide studies have shown clinal variation with no unique ecotypes (Johnston et al. 1990). It is infrequently a target species for harvest in Alberta, although it is harvested from time to time with associate species. Boggy black spruce stands are frequently excluded from harvest due to sensitive soils and poor drainage. It is represented in the protected areas network across northern Alberta, including Wood Buffalo National Park, and is extensively informally retained on the unprotected landbase. Companies with approved tree improvement Controlled Parentage Programs are working to establish gene conservation areas in applicable locations. No conservation gaps are identified.

Chokecherry (*Prunus virginiana* L.) Rosaceae

J. Krakowski

Species Characteristics Chokecherry is a widespread, fairly common, shade-intolerant tree to tall shrub growing usually up to six metres but occasionally to ten metres in disturbed and well-drained sites. It extends across Canada to around 58°N, with disjunct populations further north. Its range extends south into Texas and Mexico, and is generally absent from the west coast except the Georgia Lowlands and California, with larger subpopulations throughout the southwest. It has a more contiguous distribution in the Midwest and eastern states (Johnson 2000). In Alberta it is commonly found in the southern half of the province, becoming restricted to valley sites then absent in far north. Leaves may have slightly serrate or untoothed leaf margins and oblong, abrubtly tapered to sharply pointed tips. Flowers are 5-petaled, white to cream and grow in tight racemes, maturing to pendant clusters of dark purple drupes with short pedicels. The bark is shiny when immature, becoming brownish to grey and matte with broad horizontal lenticels.

General Ecology The broad distribution of chokecherry enables this species to be a component of numerous ecosystems. It can form almost pure stands (usually in shrub form) in moist hollows along Grassland coulees. In Alberta, common associates include Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* var. *glauca*), aspen (*Populus tremuloides*), pin cherry (*Prunus pensylvanica)* and plains cottonwood (*P.deltoides* ssp. *monilifera*). Frequently considered a pioneer species, chokecherry occurs in all forest age classes (Johnson 2000). It is a common host of western tent caterpillar (*Choristoneura fumiferana*). Abundant fruits are an important food source for wildlife including many bird species, bears, coyotes and small mammals. The berries are prized for many edible products.

Regeneration Chokecherry sprouts prolifically from roots, especially after disturbance, including wildfire. This regeneration mode tends to produce dense thickets. It has abundant and high viability seed crops that can persist for years in soil seed banks. Seeds are dispersed widely by birds and animals. Pollination is via insects.

Evolution and Genetic Variation Horticultural cultivars have been developed, but population genetic data are not available. Chokecherry is a widely distributed shrubby tree found across a broad range. It is abundant where found due to prolific vegetative and sexual reproduction. This species is wildlife-dispersed and insect-pollinated, with a robust seed bank. It is likely adequately represented in protected areas, but detailed data is lacking. Its occurrence in both disturbed and undisturbed habitats suggest that there may not be in situ gaps, but surveys to confirm presence and abundance are indicated. Because of its vigorous and extensive root sprouting, more than 5,000 mature individuals are probably required per population to capture an adequate number of genotypes.

Engelmann Spruce (*Picea engelmannii* Parry ex Engelm.) Pinaceae

A.J. Gould

Government of Alberta

M. Mochulski

Species Characteristics Engelmann spruce is a long-lived tree, often 25 to 30 metres or tallerwith a narrow spire-like crown and drooping lower branches. At higher elevations it grows as a krummholz shrub. The bark is loose, scaly and red-brown to grey. Twigs are grayish to light brown and somewhat hairy. Leaves are bluish-green, four-sided, and curved with tips flattened and blunt to sharp pointed. The leaves are not particularly stiff, are aromatic when crushed, and have two white lines of stomata on the top and underside of the leaf.

Seed cones are pale brown, narrowly oval, three to eight centimetres long, growing on the same tree as pollen cones. Seed scales are papery, tapered at both ends and have a ragged outer edge. Similar species in Alberta are black spruce (*P. mariana*) and white spruce (*P. glauca*), with which it frequently introgresses; there is an extensive hybrid zone.

General Ecology Engelmann spruce grows at high elevations from the Mexican border to north-central British Columbia. In the northern part of its range, it may be found in cold valley bottoms as low as 1,200 metres. It grows best on deep, well-drained loam soils.

In Alberta, Engelmann spruce is a subalpine species along the western border to about 54°N. It is commonly associated with subalpine fir (*Abies lasiocarpa*), lodgepole pine (*Pinus contorta* var. *latifolia*), whitebark pine (*P. albicaulis*) and occasionally subalpine larch (*Larix lyallii*). Hybrids between Engelmann and white spruce are common and form a wide altitudinal band of introgression between 1,450 metres in the south dropping to around 1200 metres in the north, and 1,800 metres at the upper limit. Genotypic studies confirm hybrids are widespread and not always identifiable from morphology.

Regeneration Regeneration is by seed except at the upper limit of tree growth where rooting of buried branches can regenerate trees dwarfed by snow and slow growth. Seed production can begin at age 15, reaching maximum production at 200 to 250 years, with good seed crops every two to six years.

Seedlings develop on a variety of seedbeds and can survive under low light. Although early growth is slow, Engelmann spruce can grow vigorously for 300 years and become the largest of the high mountain species. The species, often in combination with subalpine fir, forms stable, self-replacing plant communities in the absence of disturbance. On northern exposures, Engelmann spruce and subalpine fir forests are self-perpetuating, but on southern exposures disturbance sets back succession considerably.

Evolution and Genetics Five spruce species are native to Canada, and three to Alberta, Engelmann spruce, black spruce and white spruce. Natural hybrids between Engelmann and black spruce have not been reported. Hybrids with white spruce are common, and many genetic markers are available to quantify the amount of introgression and other genetic attributes (de la Torre et al. 2014). Considerable genetic variation is found in Engelmann spruce for growth, ontology, cold hardiness and biochemical traits (Rajora and Dancik 2000). Variation among populations is related to geography and postglacial expansion, with strong elevational and latitudinal trends (Ledig et al. 2010).

Engelmann spruce is is common and abundant in the Rocky Mountain Natural Region, where it is extensively protected in the national and provincial parks. Many studies have documented extensive introgression with white spruce to the west, and at lower elevations. No conservation gaps are identified.

Green Ash (*Fraxinus pennsylvanica* Marsh.) Oleaceae



J. Krakowski

Species Charactristics Green ash is a medium sized deciduous tree (to 20 metres in Canada) with finely grooved grey bark and a rounded crown, typically with a single stem. It is classed as a species that occurs in stands ranging from primary colonization to climax (Gucker 2005). Pinnately compound leaves have a terminal leaflet the same size as the other leaflets, which have entire margins. Leaves are arranged in opposite fashion on the branch and leave prominent rounded V-shaped scars. Stems terminate in dark to black minutely hairy valvate bud scales. Pollen and seed are produced on separate trees on relatively inconspicuous flowers. Female fruits develop into clusters of green pendant samaras. There are no related tree species in Alberta.

General Ecology Green ash extends from the prairie provinces to the maritimes to the Atlantic and the Gulf of Mexico, excluding the Florida panhandle. In Alberta, it is at the western limit of its Canadian range; it penetrates along river systems in the east-central part of the province. It is extensively naturalized following widespread introductions as a horticultural specimen tree. Green ash is moderately shade tolerant in northern populations, becoming less tolerant further south (Kennedy 1990). This species is typically found in floodplains, riparian areas, and mixed broadleaf woodlands in Canada. Common associates in Alberta are aspen (*Populus tremuloides*), plains cottonwood (*P. deltoides* ssp. *monilifera*), and balsam poplar (*P. balsamifera*).

Green ash has a broad ecological niche but grows well on medium textured richer sites with no moisture deficit. It is highly tolerant of flooded or seasonally flooded soils, and slightly alkaline soils. It is vulnerable to fire, but regenerates abundantly after sites are burnt or harvested (Gucker 2005).

Regeneration Green ash reproduces from a mixture of seed and root and stump sprouting. It is a vigorous and prolific reproducer after fire and disturbance; the intensity and mode of disturbance affects the reproductive strategy of this species. Mast seed crops range from every one to five years or more, and seeds may retain viability for years in the soil (Kennedy 1990). Wind, water and wildlife all contribute to seed dispersal. Flowering begins at about 15 years but depends more on size and competition than age.

Evolution and Genetics Several subspecies of this species are proposed but not recognized by taxonomic authorities. Green ash does not hybridize with any congeners in Canada. There have been numerous studies quantifying genetic diversity within and among populations on growth, seedling traits, drought tolerance, cold hardiness, sexual dimorphism, and rooting habit (Kennedy 1990). No data was collected from Alberta, but the above studies have contributed to several tree improvement programs in the southern part of the species' range where it is an important commodity tree in managed forests.

Jack Pine (*Pinus banksiana* Lamb.) Pinaceae

A.J. Gould

M. Mochulski

Species Characteristics Jack pine is a relatively short-lived species (over 200 years) ranging from a small, shrubby tree to a tall, straight tree. Bark is reddish-brown and flaky. Leaves are yellow-green in summer changing to purple-green in winter. Leaves are held in bundles of two, often twisted, sharp-pointed and with toothed edges. Seed cones and pollen cones are produced on the same tree and seed takes two seasons to mature. Seed cones are tan and curved with smooth scales and, sometimes, tiny prickles. Lodgepole pine (*P. contorta* var. *latifolia*) is a similar species in Alberta; the two hybridize where they overlap, producing *P.* x *murraybanksiana*. Hybrids may be impossible to accurately distinguish by morphology.

General Ecology Jack pine grows further north than any other North American pine, extending from the Maritimes to the Mackenzie River. In Alberta, it is the major forest conifer in the northeast where soils are predominantly coarse textured. In the northwest it is increasingly replaced by aspen due to more prevalent finer-textured parent materials. Jack pine is extensive on suitable sites from northern Alberta to the Maritimes. Where the ranges of jack pine and lodgepole pine overlap, mixtures of trees resembling each species and hybrids with intermediate characteristics occur, but these morphological characteristics do not align well with genetic identities or relative genetic contributions of each species.

Jack pine is most frequently found at lower altitudes and on soils with high sand or gravel content, often in pure stands initiated after fire. It is classed as a species of early succession except on the driest sites where it is an edaphic climax. In mixed stands, the most common associates are aspen (*Populus tremuloides*), paper birch (*Betula papyrifera*) and black spruce (*Picea mariana*).

Regeneration Jack pine reproduces only by seed. Seed production begins as early as age 4 or 5 and some seed is produced in most years. Serotinous cones may remain closed for many years and fire is an important agent in opening cones to allow seed dispersal, which is mainly by wind.

In Alberta, regeneration by natural seeding is the typical method for replacing harvested stands of jack pine. A relatively small percentage of harvested/reclaimed lands are artificially regenerated by planting. Natural regeneration is most successful on mineral seedbeds. Seedling growth of jack pine is slow during the first few years, then rapid where nutrition, moisture and light are adequate.

Evolution and Genetics The subsection of pines containing jack pine (*Contortae*) has four species, all in North America but only two in Alberta. Hybrids with lodgepole pine are common where the distributions of the two species overlap in west-central Alberta and some locations in Saskatchewan and B.C. Hybrid jack pine populations tend to have straighter stems and finer branches, tolerate a broader range of site types, and are more desirable for commercial forestry. Pure jack pine exhibit less pest incidence than pure lodgepole or hybrids (Wu et al. 1996).

Significant genetic differences associated with provenance have been shown in several genetic tests. Movement of seed northward up to 160 kilometres resulted in better growth than southern or local provenances (Magnussen and Yeatman 1979, 1988). Large variation among provenances was found for early height growth in an Alberta study, with geographic trends being extremely broad regionally (Hyun 1979). Genetic variation among individuals of jack pine has been reported for a wide variety of traits including crown form, growth rate, shoot elongation and tolerance to many insects and diseases. Numerous tree improvement programs have been developed for jack pine. The Alberta program emphasizes form and wood quality, while maintaining volume production.

Where present, it grows in dense stands, and includes an extensive hybrid zone with lodgepole pine across most of its Alberta range (Cullingham et al. 2012). While it is a harvested species, there extensive areas of non-merchantable stands, as well as many populations in protected areas. Wood Buffalo and Elk Island National Parks; Birch Mountains, Colin-Cornwall Lakes, La Butte Creek, Marguerite River, Maybelle River, and Richardson River Dunes Wildland Provincial Parks all support viable populations of jack pine and associated hybrids. Companies with approved tree improvement Controlled Parentage Programs are working to establish gene conservation areas in applicable locations. No conservation gaps are identified.

Limber Pine (*Pinus flexilis* James) Pinaceae

H. Eijgel

A.J. Gould

Species Characteristics Limber pine is a small to medium-sized (to 25 metres tall) tree that grows slowly but can live for over 1,000 years. In mature trees, the trunk is tapered and often twisted, with branches extending for most of the bole's length. Young branches of many trees are sometimes flexible, but may also be brittle. The bark is pale grey, smooth in young trees, changing to rough, scaly plates as the trees mature. The needles grow in bundles of five; they are five to ten centimetres long and one to one-and-a-half millimetres wide, and have whitish lines of stomata more conspicuous on upper needle surfaces than lower surfaces.

Pollen strobili and seed cones develop on the same tree; pollen grows in the lower crown and seed cones, which are narrowly ovoid and eight to 20 centimetres long, grow throughout the crown. Pollen cones are yellow, turning orange or brown as they mature; seed cones are green, turning brown and opening as they mature. The seeds are wingless or may have vestigial wings. Whitebark pine (*P. albicaulis*), is a similar five-needled pine that usually occupies habitats at higher elevations, although they sometimes co-occur. The two species are best distinguished by their cones.

General Ecology Limber pine has an extensive but patchy distribution from the Rocky Mountains in southeastern British Columbia and western Alberta south to New Mexico, with scattered populations to the west, in the Great Plains, and the midwestern U.S. It reaches its northern distribution limit in the Highway 11 corridor of Alberta. It has a large altitudinal range from 100 to 3,600 metres. Further south, it intergrades with southwestern white pine *P. strobiformis* which grows in similar habitats.

Limber pine is typically a montane species of dry, rocky sites, growing on ridges, screes and gravel creek beds, as single trees or in small open groves, particularly on calcareous soils and sandstone. Shade-intolerant, on forested sites it is usually a pioneer species that colonizes sites after fire or tree removal. Species commonly associated with limber pine in Alberta are lodgepole pine (*Pinus contorta* var. *latifolia*), Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) and whitebark pine. Limber pine is ecologically important in providing shelter and food for wildlife and for watershed protection.

Regeneration Reproduction is by seed, with good seed crops produced every 3 to 5 years. Pollination occurs in late spring followed by fertilization almost a year later. The cones and seeds then mature rapidly. The cones change from green to brown and seeds are dispersed starting in July, ending around October.

Seeds are predominantly dispersed by Clark's nutcrackers (*Nucifraga columbiana*), squirrels, and chipmunks. Clark's nutcrackers cache the seeds of this pine, as well as of whitebark pine, carrying up to 100 seeds per trip in sublingual pouches. The seeds are usually buried in a cache of one to 12 seeds on windswept ridges, southerly slopes, or rocky outcrops where snow does not tend to accumulate. Limber pine has, in addition to single trunk and multi-trunk growth habits, a clustered form of growth, as a result of caching by nutcrackers. The clusters are typically made up of stems of genetically different but related individuals that may only be distinguished by genotyping. Studies in the Kananaskis Valley in Alberta have indicated rapid recolonization by this species after fire due to seed dispersal by nutcrackers.

Evolution and Genetics Five species of pine are found in Alberta and limber pine is classified with two other species, whitebark pine and western white pine (*P. monticola* Douglas ex D. Don) among the five-needled haploxylon pines. No natural hybrids have been reported among these species, but they are all cross-compatible when grafted.

Genetic variation in growth and response to blister rust inoculation traits have been demonstrated through progeny testing of selected parents. Parents and progeny that have resistance to blister rust are established in orchards for seed production. Genetic studies show considerable diversity within populations and limited variation between populations, with individuals from within a cluster being more closely related than individuals from different clusters within the population. Some regional patterns for adaptive traits including phenology and cold hardiness have been identified; limber pine is among the most plastic and generalist conifer species.

Limber pine is undergoing rapid decline. Slow growth, late maturity, and persistent threats make gene conservation challenging. This species is very well conserved across its Alberta range in the network of Rocky Mountain and adjacent Foothills Parkland protected areas, but passive in situ conservation is inadequate to mitigate or reverse threats to the species. In situ gene conservation must include active restoration with genetically diverse disease resistant seedlings with moderate to high levels of white pine blister rust, and creation of suitable regeneration sites to be effective.

Lodgepole Pine (*Pinus contorta* var. *latifolia* Engelm. ex Wats.) Pinaceae

L. Allen

C. Crell

Species Characteristics Lodgepole pine is a medium sized tree with a straight stem. Although it is a relatively short-lived species (250 years), some trees live older than 500 years. It grows 30 metres or taller, usually in dense, even aged stands. In less common open stands it forms broad, bushy crowns. The bark is thin with orange-brown to grayish scales. Needles are dark green to yellowish green, in sharp-pointed bunches of two, and are often twisted in a spiral. Seed cones and pollen cones are produced on the same tree and seed takes two seasons to mature. Seed cones are tan, woody, ovoid or conical, two to five centimetres long, spreading or reflexed and have a sharp prickle at the edge of the seed scale.

General Ecology Lodgepole pine is found from the central Yukon to Mexico, although distribution is spotty south of central California and central Colorado. The species ranges from the Pacific Coast eastward to the Black Hills of South Dakota. In western Alberta, lodgepole pine is common at mid- to higher elevations in the foothills. Across the north it occurs at the tops of boreal hill systems where it often hybridizes with jack pine growing below. A large isolated population, relict from the last interglacial, is native to the Cypress Hills.

Associated species include Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*). At lower elevations, aspen (*Populus tremuloides*), white spruce (*Picea glauca*), paper birch (*Betula papyrifera*) and in the south, Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) may be mixed in pine stands. Jack pine (*P. banksiana*) is a similar species in Alberta; the two hybridize where they overlap, producing *P*. x *murraybanksiana*.

Lodgepole pine is most common in mountains and foothills where it can occupy well- to poorly-drained soils, including calcareous substrates. Wildfire often predominates stand initiation, followed by self-thinning. Tolerance to frost, poor soil drainage, and infertile soils convey early competitive advantages to lodgepole pine over many associated species.

Regeneration Lodgepole pine regenerates exclusively from seed, beginning at five to ten years of age; good crops are frequent. Serotinous cones are common but some populations have non-serotinous cones. Seeds held in cones can germinate after decades. Natural regeneration is abundant following disturbance, especially fire. Natural regeneration of lodgepole pine is usually abundant, up to 200,000 trees per hectare. High density young stands may stagnate due to low vigour from competition, and responses to treatment are inconsistent. Regeneration by planting is common to achieve target densities, and mechanical scarification after harvest exposes mineral seedbeds to high temperatures to facilitate cones opening and seeds germinating.

Evolution and Genetics The taxonomic subsection containing lodgepole pine (*Contortae*) has four species in North America but only two in Alberta. Of the four varieties of lodgepole pine, only *latifolia* occurs in Alberta. Variation associated with geography has been well studied and the gradual patterns of genetic change with distance, especially elevation, are typical of broadly distributed species. In Alberta, genetic studies have shown population variation related to elevation, origin climate, wood properties, reproduction, and growth and disease resistance. The latter traits also exhibit considerable family variation.

Hybridization with jack pine, and parental back-crosses, occurs in a broad zone in west-central Alberta and in the tops of boreal hill systems in the north, extending into B.C. and across the boreal; DNA studies indicate hybrids may be impossible to accurately distinguish by morphology (Cullingham et al. 2012). This hybridization may been significant in the evolution of pest resistance in lodgepole pine (Wu et al. 1996). A positive relationship has been reported between pest damage of populations and the proportion of lodgepole pine DNA. Genetic variation for productivity within populations of lodgepole pine is being utilized in tree improvement programs, including several in Alberta.

Lodgepole pine is a major timber species in Alberta, and partners in approved tree improvement programs are responsible for establishing in situ gene conservation areas. Lodgepole pine is well represented in protected areas throughout the Rocky Mountains. In the foothills and boreal, it is represented in Chinchaga, Dunvegan West, Hay-Zama Wildland Provincial Parks; Pinto Canyon, Sand Lake, and Wildhay Glacial Cascades Natural Areas; Two Lakes and William A. Switzer Provincial Parks. No conservation gaps are identified.

Manitoba Maple (*Acer negundo* L.) Aceraceae

Government of Alberta

L. Allen

Species Characteristics Manitoba maple is a small to medium lowland deciduous tree reaching (rarely) 20 metres in height. Its life span is about 60 years. The trunk often divides near the base into several stems and the crown is broad and irregular. The bark is smooth and light grey in young trees, becoming furrowed with narrow ridges as the trees mature. Manitoba maple is unique among maples, and therefore, readily distinguishable from them, in having pinnately compound rather than simple palmate leaves. Its leaves are five to 12 centimetres long, with three to nine coarsely toothed leaflets. The twigs are glaucous with a coating of a waxy white powder. Male and female flowers are produced in drooping clusters on separate trees.

General Ecology Manitoba maple is widespread across central North America, extending as far south as Guatemala. In Alberta, it is at the western limit of its Canadian range; it penetrates along river systems in the east-central part of the province. Manitoba maple grows best in moist, disturbed ground and often follows the pioneering cottonwoods (*Populus trichocarpa*, *P. balsamea*) and willows (*Salix* spp.) in colonizing alluvial bottomlands and the banks of rivers and streams, as well as other seasonally flooded areas. It can also be a pioneer invader of old fields.

The species is somewhat tolerant of shade and, once established, can tolerate drought. It tolerates a variety of soil types but grows best in deep alluvial soils. Its twigs, buds and fruits are an important food source for wildlife.

Regeneration Regeneration is by seed and stump sprouting, with no known vegetative reproduction (Nybom and Rogstad 1990). Seed production begins at eight to 11 years of age. The typical maple fruits, consisting of a pair of "keys," each comprising a seed and a single wing, mature in autumn. Produced in abundance and wind-dispersed throughout the winter, the fruits constitute an important winter food source for wildlife.

Evolution and Genetics The maples are a very diverse genus with many species. Two are found in Alberta, but Douglas maple (*A. glabrum*) is a shrub so Manitoba maple, the only maple tree species found in Alberta. Two of the many varieties of this species occur here: *A. negundo* var. *interius* which is rare, and the more common form, var. *violaceum*. Due to its tolerance of cold and drought, fast growth and ease of cultivation, the tree has been widely planted for shelterbelts, along streets and in gardens throughout the province and is found virtually anywhere where there is human habitation. Native populations are thought to be relatively rare in Alberta, as far as can be determined but wild and naturalized forms are impossible to distinguish by eye so populations that are possibly native are identified as such on the basis of their distribution. Naturalized and native populations interbreed. Manitoba maple is considered an invasive species in Europe due to its vigorous growth and fecundity (Porté et al. 2011; Lamarque et al. 2013, 2014).

In studies in the American southwest, genetic differences between populations were observed in such characters as response to photoperiod, seed germination and stratification requirements, seed weight, tracheid length, frost tolerance and chlorophyll level. Considerable variation in leaf coloration characters and other morphological traits has also been observed, but has not been linked to particular geographic ranges. Nybom and Rogstad (1990) found genotypically similar individuals were more likely to be geographically closer.

Narrowleaf Cottonwood (*Populus angustifolia* James) Salicaceae



C. Crell

Species Characteristics Narrowleaf cottonwoods are small trees growing to 15 metres high and 30 centimetres in diameter, with a lifespan of 100 to 200 years. Slender, with narrow conical crowns and white branches and twigs, they bear an overall resemblance to species in the closely related willow (*Salix*) genus. Their smooth, whitish-green bark becomes furrowed at the base in mature trunks. The narrowly lanceolate leaves, five to nine centimetres long, are more typical of willows and readily distinguish this tree from other poplars. Pollen and seeds are produced on different trees.

General Ecology This species is distributed across southern Alberta and southern Saskatchewan south to California and across the Great Plains as far east as South Dakota and Nebraska. It establishes in pure stands along river floodplains, or mixed with other poplar species, and commonly with its interspecific hybrids, which may outnumber it. In Alberta, it is particularly common along the Oldman, St. Mary and Waterton Rivers, as it appears to favour steeper river gradients than the plains cottonwood (*P. deltoides* ssp. *monilifera*). It has been considered a keystone riparian species.

Along with other *Populus* species and hybrids, it is of high ecological importance, contributing enormously to biological diversity and shading along riparian corridors in the plains. It provides food and cover for a variety of wildlife, particularly insects and birds, and nesting habitat for the latter. Its leaves shed annually into the riverbed, providing nutrients for aquatic life.

Regeneration The mode of reproduction for narrowleaf cottonwood is characterized by flexibility. Despite good annual seed production, seedling establishment takes place relatively infrequently, being dependent upon the right conditions of water flow, and exposure of sand bars or gravel beds at the time of seed release (seeds have very limited longevity). Each seed is equipped with a tuft of cottony hairs to aid in wind dispersal, although dissemination by water also takes place.

Seedling establishment requires adequate soil moisture during the initially slow seedling root growth. Studies of riparian poplars along the Oldman River in southwestern Alberta have revealed extensive propagation as clones by root suckering in this species. Shedding of branches that subsequently root provides another means of regeneration.

Evolution and Genetics Taxonomy of genus *Populus* has undergone substantial revision with the use of genomic tools. Narrowleaf cottonwood is closely related balsam poplar (*P. balsamifera*), which is also found in Alberta, and the two hybridize where they overlap. Hybrids between narrowleaf cottonwood and plains cottonwood are classified as lanceleaf cottonwood, (*P.* x *acuminata*). Although hybridization is generally most common among members of the same section, in southern Alberta, analyses of both morphological and chemical traits indicate that balsam poplar, plains cottonwood and narrowleaf cottonwood interbreed freely and produce a trispecific hybrid swarm (Brayshaw 1966).

Genetic variation, other than as expressed in the many forms resulting from natural hybridization, has been reported for narrowleaf cottonwood for resistance to insects (Whitham et al. 2008; Zinkgraf et al. 2016).

Narrowleaf cottonwood is Priority 5: not rare, not commercially planted, no tree improvement, no unique factors - occurs in a few scattered populations in southern Alberta lower foothills and grasslands, with a more extensive, somewhat contiguous range extending as far south as northern Mexico and Texas. It hybridizes with associated poplar species. Growing in riparian areas, it falls outside the managed forest region (Green Area). No population genetic data or accurate range map is available. Its mixed sexual and clonal reproduction mode would require over 5,000 trees to capture 5,000 genotypes, but the exact number is unknown. Riparian buffers, private land holdings, and existing provincial protected areas likely contain adequate samples of Alberta populations. Twin River Heritage Rangeland and Milk River Natural Areas, Writing-On-Stone Provincial Park, Oldman River and St. Mary Reservoir Public Recreation Areas may all support pure or mixed populations of narrowleaf cottonwood. Some field verification is recommended.

Paper Birch (Betula papyrifera Marshall) Betulaceae

Paul Rothrock

Species Characteristics Paper birch is a medium tree with bark that is white when mature, and reddish brown when immature, that peels in sheets. It rarely lives more than 150 years. Twigs are brown with prominent glands and lenticels, and slender with long hairs. Leaves are serrated and with tufts of hair in the axils of veins. Pollen and seed are produced on the same tree in pendant catkins. Related tree species in Alberta are water birch (*B. occidentalis* Hook.) and Alaska birch (*B. neoalaskana* Sargent), which all hybridize.

General Ecology Paper birch follows the northern limit of tree growth from Labrador to northwest Alaska. The southern limit extends from 40°N in the east to 45°N in the west, with a ragged southern limit. Paper birch is an early successional species, often following fire. It is shade intolerant. In addition to forming pure stands, it is often associated with aspen (*Populus tremuloides*), white spruce (*Picea glauca*), black spruce (*P. mariana*), lodgepole pine (*Pinus contorta* var. *latifolia*), jack pine (*P. banksiana*) and their hybrids, as well as balsam fir (*Abies balsamea*). It grows best on well-drained sandy or silty soils. Dieback due to frequent drought has been observed in many parts of the southern portion of the range, causing cumulative effects such as increased susceptibility to pathogens and insects.

In Alberta, paper birch is a minor component of upland stands throughout northern boreal forests. It frequently occurs in these forests as an edaphic species associated with seepage areas and wet depressions on both mineral and shallow organic soils. At lower elevations in boreal hill systems and the northern sections of the Rocky Mountain foothills, paper birch is more common and forms both pure and mixed stands on upland sites. Disjunct populations are reported from the Crowsnest Pass and Cypress Hills. Peripheral populations occur along streams and rivers extending from boreal and foothills forests into the parkland.

Regeneration Paper birch reproduces mainly by seed, maturing at age 15 in forests although seed can be produced by the second year in nursery culture. Large seed crops may are periodic and the small, winged seeds are released throughout the year and dispersed for long distances by wind, especially on glazed snow. The small seed is fragile and seedlings are most easily established on partially shaded mineral soil or rotting wood. Birch seed may lie dormant for a year or two until moisture conditions are favourable for germination. Paper birch has early rapid growth. Individual trees gain a dominant position quickly and substantial mortality follows unless suppressed trees are released from competition.

Vegetative reproduction is possible through stump sprouts, but declining in vigour and number as trees age, and is far less common than reproduction through seed.

Evolution and Genetics The birches are taxonomically complex in North America with up to 16 recognized species and two subspecies, and many varieties and hybrids that are not really possible to accurately distinguish based on morphology (Furlow 1997; Schenk et al. 2008). Paper birch is hexaploid (Furlow 1997) making genotypic studies challenging. Alberta has six native species but only Alaska, white and water birch (*B. occidentalis*) are classified as trees. Natural hybrids of Alaska birch with white and water birch, as well as with dwarf birch (*B. glandulosa*), have been reported, and zones containing hybrid swarms of varying degrees of introgression are common (Schenk et al. 2008).

Genetic differences associated with the geographic origin of seed have been reported from range-wide genetic testing and regional testing, though genetic tests in Alberta have not been conducted. Tests show greater growth potential of southern sources than northern sources, but there were some exceptions to the general pattern. There is substantial genetic variation within populations in a variety of traits including growth rate, drought tolerance, age at which bark becomes white and resistance to insects. There are improvement programs for paper birch in Europe, and some genecological studies have been done in North America. No conservation gaps are identified.

Peachleaf Willow (*Salix amygdaloides* Anderss.) Salicaceae

L. Allen

Species Characteristics Peachleaf willow is unusual among Alberta willows (*Salix* spp.) in reaching tree size (up to 20 metres in height and 40 centimetres in diameter). It is the tallest willow in the prairie provinces. It often has several trunks and a broad irregular crown. The bark of twigs and branches is smooth and yellowish-grey, becoming broadly and irregularly furrowed on old trunks. The leaves are lanceolate, five to 14 centimetres long, and taper to a long, pointed tip. They are bright yellow-green above and whitish or glaucous beneath. Stipules are absent or inconspicuously minute. Pollen and seed catkins are about three to six centimetres long, produced on leafy branchlets on separate individuals. Occasionally it has perfect flowers (Fryer 2012). The pollen catkins are unusual in having four to seven stamens, most commonly five. Peachleaf willow could be confused with other willow species that occur in similar habitats, particularly hungry willow (*S. famelica*), but its arboreal habit and slender leaves make it relatively distinctive.

General Ecology Peachleaf willow occurs from southern Quebec across the southern portion of the prairie provinces to southeastern British Columbia and southwards through the U.S. as far as Mexico. Sparse and disjunct populations occur in the southeast U.S., extending into the alpine in suitable sites in the southwest (Fryer 2012). In Alberta, it occurs predominantly in the river valleys of the southeast, although it may also grow along lakeshores and in swamps. It can be the dominant species of a floodplain, or grow mixed with cottonwoods (*Populus* spp.), green ash (*Fraxinus pennsylvanica*.) and other willows. In providing cover, shade, nesting opportunities and food for birds and insects, it is a very important component of plains riparian ecosystems. It requires moist sites and is highly tolerant of flooding.

Regeneration Peachleaf willow regenerates by seed and from rooted branch segments. Pollination is both by wind and insects (Ostaff et al. 2015). The fruiting catkins bear hairless capsules that split into two to release abundant cottony seeds that are dispersed by wind. The species may be dependent on natural river flows and flooding to provide open, moist seedbeds on which seedlings can establish.

Evolution and Genetics Among the many species of willow, peachleaf willow is one of the two willow species found as trees in Alberta. Natural hybridization is thought to be uncommon due to its very short pollen receptivity period (Fryer 2012).

While quantitative genetic variation has not been studied in peachleaf willow, some phylogenetic work has been done (Barkalov and Kyzyrenko 2014; Chong et al. 1995).

Peachleaf willow is restricted to moist sites in Alberta's southeast grasslands, where it is at the northern limits of its nearly continent-spanning range. Detailed range and inventory data is lacking. Likely occurrences in protected areas include Cypress Hills, Dinosaur, and Writing-on-Stone Provincial Parks; Milk River and Twin River Heritage Rangeland Natural Areas. Some field verification is recommended.

Pin cherry (*Prunus pensylvanica* L.) Rosaceae

J. Krakowski

Species Characteristics Pin cherry is a widespread, abundant, shade-intolerant tall shrub to tree that grows in disturbed and well-drained sites. It is found from Newfoundland to New England, along the Midwest, with populations throughout the Yellowstone and a large disjunct occurrence in southwest California. It stretches across Canada to central and south coastal British Columbia into the central interior, with isolated occurrences in the north (Johnson 2000). Typically mature trees reach three to eight metres, but can grow much larger (Anderson 2004). Leaves are simple, oval to lance-shaped and have singly serrate leaf margins and tips that gradually taper to a point. Flowers are five-petaled, white and set on long stalks, in loose clusters (umbels) of five to seven flowers, maturing to bright red drupes with long pedicels. The fruits are sour but edible, with a single large stone. The bark is shiny, smooth and dark red-brown when immature, becoming brownish to grey and matte with broad horizontal lenticels.

General Ecology This fast-growing tree is found on dry to moist sites, from uplands and hillsides to along coulees and river banks, often on dry or sandy soils (Wilkinson 1990). It is commonly associated in Alberta with aspen (*Populus tremuloides*), chokecherry (*Prunus virginiana*) and in the west with Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) (Johnson 2000).

Regeneration Pin cherry reproduces abundantly from coppice, root sprouts, and by seed (Anderson 2004) which is dispersed by gravity and also by birds and wildlife. Ingestion by wildlife, exposure to elements to break down mechanical and biochemical germination inhibitors, and stratification, all aid germination. The seed bank remains viable for over 30 years (Wendell 1990; Anderson 2004). The showy flowers are insect-pollinated.

Evolution and Genetic Variation No genetic data are available for this species. Pin cherry is a broadly distributed shrubby tree that reproduces prolifically and is wildlife-dispersed and insect-pollinated, with a robust seed bank. It is likely adequately represented in protected areas, but detailed data is lacking. Surveys to confirm presence and abundance are indicated. Its shade intolerance and pioneer status suggest that disturbed sites are priority for assessment but that in situ gaps should be passively managed through inventory because of the dynamic nature of disturbance. Because of its vigorous and extensive root sprouting, more than 5,000 mature individuals are probably required per population to capture an adequate number of genotypes.

Plains Cottonwood (*Populus deltoides* ssp. *monilifera* (Ait.) Eckenw.) Salicaceae

A.J. Gould L. Allen

Species Characteristics Plains cottonwood is a medium-sized to tall deciduous tree, reaching 30 metres in height with a lifespan of up to 150 years. It has an open, spreading crown and smooth, yellowish grey bark that becomes furrowed as the tree gets older. The leaves, borne on flattened leaf stalks, are triangular with long tapering tips. Male and female flowers are produced in similar catkins five to seven centimetres long, but on separate individuals. Fruiting catkins extend 15 to 25 centimetres, and are composed of numerous green dehiscent capsules whose many seeds each bear a tuft of cottony hairs to aid in wind dispersal.

Plains cottonwood is separated from eastern cottonwood (*P. deltoides* ssp. *deltoides*) mainly by leaf and bud characters; the two have distinct but overlapping ranges occupying the west-central and eastern parts of the North American continent, respectively.

General Ecology Plains cottonwood is distributed westwards from southern Manitoba to southeastern Alberta, and southwards down through the Great Plains to northern Texas and northeastern New Mexico. At its eastern limit it intergrades with the eastern cottonwood. Plains cottonwood is a pioneering species, growing along watercourses in moist, fertile floodplains and bottomlands, in pure, often even-aged, stands, in hybrid stands with other *Populus* species, or in association with trees and shrubs such as willows (*Salix* spp.) and Manitoba maple (*Acer negundo*).

Cottonwoods have enormous ecological value, providing cover and food for wildlife, including fish and freshwater arthropods in riparian and lotic systems, habitat for cavity nesting birds, and important arthropod habitat. The shade they provide, their location and the fact that they create habitat for wildlife, provide high amenity value for people.

Regeneration Plains cottonwood has multiple reproductive modes. Good seed crops are produced almost every year in trees ten years and older. The seeds are widely dispersed by wind and water. Vegetative reproduction is by root and stump sprouts. Regeneration of stands by sexual reproduction occurs irregularly at five to ten year intervals because of the specific conditions needed for seedling establishment. Abundant soil moisture in the early stages of seedling establishment is critical to support sustained root growth. In Alberta, regulated river flows that preclude spring flooding are considered to be a major factor in paucity of regeneration of riparian poplar stands. Seedlings and young trees also require full sunlight and absence of root competition to grow well.

Evolution and Genetics Taxonomy of genus *Populus* has undergone substantial revision with the use of genomic tools. Hybrids between plains cottonwood and balsam poplar are classified as *P.* x *jackii*. Hybrids between plains cottonwood and narrowleaf cottonwood are classified as lanceleaf cottonwood (*P.* x *acuminata*). Although hybridization is generally most common among members of the same section, in southern Alberta, analyses of both morphological and chemical traits suggest that balsam poplar, plains cottonwood and narrowleaf cottonwood are thought to interbreed freely and produce a trispecific hybrid swarm (Brayshaw 1966).

Plains cottonwood populations vary in adaptive traits, particularly fall photoperiod and cold hardiness (Ying and Bagley 1976), but not for spring traits (Friedman et al. 2011). Plasticity in morphology has also been recorded (Yeager 1935). Evans et al. (2015) inferred rapid and continuing postglacial northern range expansion, high diversity, and a very high census and effective population size for northern (Northern Rocky Mountain and Wasatch ranges, including Alberta) sources, which bode well for gene conservation.

The range of plains cottonwood extends through southeast Alberta and the Prairie regions throughout the central and southeast U.S. It is not a timber species and does not occur in the operational forestry region of Alberta, but hybrids of *P. deltoides* with other poplars are cultivated for pulp production, typically further south than Alberta. Some forest companies established plantations of hybrid poplars in boreal Alberta on private lands in past decades, but sufficient moisture was not consistently available to support continued planting or breeding programs. Detailed range and inventory data is lacking; Conservation issues are similar to narrowleaf cottonwood. This species appears secure in Alberta and no conservation gaps are identified.

Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Mayr.) Franco) Pinaceae

H. Lazaruk

L. Allen

Species Characteristics Rocky Mountain Douglas-fir, sometimes called interior Douglas-fir, is a medium-sized tree with thick, deeply furrowed bark. It can live for hundreds of years. Needles are two to three centimetres long and spirally arranged, though they may appear two-ranked, especially on lower branches. Buds are pointed. Seed and pollen cones are on the same tree. Seed cones are five to ten centimetres long, upright and green initially, becoming brown and pendant after pollination. Three-pointed bracts extend considerably beyond cone scales.

General Ecology Rocky Mountain Douglas-fir occurs from central British Columbia to central Mexico. It is found mostly at mid-elevations in the north and higher elevations in the southern portion of its range. There are many scattered peripheral populations south and east of Idaho. Rocky Mountain Douglas-fir is a keystone species of Alberta's montane zone, with outlier populations along river valleys eastward from the Rocky Mountains and on steep southern grassy slopes and cliff faces in the southern subalpine.

Rocky Mountain Douglas-fir is wildfire-adapted and moderately shade-intolerant upon maturity. It typically occupies warmer, drier sites than associated montane species and is limited within its natural range in Alberta by cold temperatures and drought. It does not tolerate saturated soils but has a high tolerance of calcareous soils. Due to a vigorous and plastic rooting habit it has a competitive advantage on high bulk density and shallow soils underlain by bedrock.

Although commonly an early successional pioneer species, long-lived Rocky Mountain Douglas-fir maintains a successional self-perpetuating stand type. Its most common associates in Alberta are lodgepole pine (*Pinus contorta* var. *latifolia*), aspen (*Populus tremuloides*), white spruce (*Picea glauca)*, and at higher altitudes, subalpine fir (*Abies lasiocarpa*).

Regeneration Rocky Mountain Douglas-fir naturally regenerates from seed, beginning around age 20 and peaking in seed production at ages over 150. The best natural regeneration occurs in partial shade to reduce moisture loss. Seed predation is a common phenomenon as many bird and small mammal species use the seeds as a major or minor component of their diet. Rocky Mountain Douglas-fir is the primary alternate food source for Clark's nutcracker (*Nucifraga columbiana*) when whitebark cone crops fail in Canada.

Evolution and Genetic Variation Two species of Douglas-fir are present in North America, one in Alberta. The variety native to Alberta is a variety often called Rocky Mountain Douglas-fir to distinguish it from the western variety called coast Douglas-fir (*P. menziesii* var. *menziesii*), although both varieties intergrade where they overlap.

Genetic variation among populations of Rocky Mountain Douglas-fir has been widely studied. Patterns of variation associated with geography show gradual genetic change across latitude and longitude, but rapid adaptive change with elevation. Growing season moisture is a key climatic driver, as are degree days and damage to upper shoots and buds caused by snowpress and early and late frosts. The species shows high growth potential in mild environments, balanced with high cold hardiness and slower growth in cold environments. Limited genetic testing of Alberta populations in southwestern Alberta has occurred. Tests show good survival and growth occurred outside the species' natural range but within its suitable climatic envelope. Genetic differences for many traits have been exploited in trees and populations and within many tree improvement programs, and there is a gene archive established in Alberta.

Rocky Mountain Douglas fir ranges from Mexico to north-central B.C.; in Alberta from the border to Willmore Wilderness Area. It is very well represented in national and provincial protected areas in the Rocky Mountain Natural Region, and in the adjacent Foothills Parkland Natural Subregion, where it also occurs on private land. Alberta has established special reserves specifically for Rocky Mountain Douglas-fir genetic and ecosystem conservation in the Rocky Mountain region. Besides the contiguous network of protected areas in the Rockies, adequate population sizes are protected in Beauvais Lake Provincial Park, Black Creek and OH Ranch Heritage Rangelands, Bob Creek, Bluerock, and Don Getty Wildland Provincial Parks; Chain Lakes and Sheep River Provincial Parks; and Emerson Creek Natural Area, among others. It is likely to increase in abundance and expand its Alberta range with climate change. No conservation gaps are identified.

Rocky Mountain Juniper (*Juniperus scopulorum* Sarg.) Cupressaceae

L. Allen

J.D. Johnson

D. McIntyre

Species Characteristics Rocky Mountain juniper is a small slow-growing tree or, on poor sites, a shrub, growing up to ten metres high, that can live for several hundred years. It has a conic or occasionally a rounded crown and can be single- or multi-stemmed. The reddish- to grey-brown bark is smooth on smaller branches, turning fibrous and exfoliating in strips or plates on larger branches. It has two leaf forms: three to six millimetre long needle leaves, which are awl-shaped and spread in three or four ranks around the twigs, and one to three millimetres long pale or yellowish scale leaves which are appressed and scarcely overlapping. Young plants bear only needle leaves, which have a conspicuous elliptic gland on the outer surface.

Male and female cones are borne on separate trees. The glaucous seed cones are berry-like, about eight millimetres in diameter, and take two years to mature, turning from pale green to dark bluish-purple. Similar species with overlapping ranges are creeping juniper (*J. horizontalis*) and common juniper (*J. communis*), which are both low-lying shrubs.

General Ecology Rocky Mountain juniper is a western species, extending into the prairies, with a scattered distribution and a wide climatic range. It ranges from the glaciated valleys of northern and central British Columbia through the foothills of the Rocky Mountains down to northern

Mexico. In Alberta, the species is uncommon, occurring in moist coniferous forests of the southwest, on slopes of prairie river systems and on rocky slopes and eroded hillsides with shallow soils at 1,200 to 2,700 metres. It may grow best in sheltered hillside ravines. Although it can occur in pure stands or as a co-dominant species in certain community types, juniper is usually a minor component of late seral or mature forest communities within most parts of its range. Shade tolerance decreases with age.

Rocky Mountain juniper is associated with a wide range of forest-shrub-grassland species. In British Columbia and Alberta at high elevations it is associated with subalpine larch (*Larix lyallii*), limber pine (*Pinus flexilis*) and whitebark pine (*P. albicaulis*), as well as common and creeping junipers; Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) and lodgepole pine (*Pinus contorta* var. *latifolia*) are common associates in montane habitats.

Regeneration Regeneration is by seed, beginning as early as ten years, reaching full production between 50 and 200 years. Each cone contains up to three seeds, which are dispersed chiefly by birds as well as gravity. Seed may remain viable for several years under proper conditions. Seed germinates in the second spring after a 14- to 16-month after-ripening period that breaks embryo dormancy, but germination may be further delayed and germination percentages are often low. Seedlings establish better on moist sites under partial shade than on drier sites, although wet sites are more susceptible to frost heaving which can be lethal.

Evolution and Genetics Rocky Mountain juniper is in section *Sabina* of genus *Juniperus*, but the taxonomy is disputed (Adams and Demeke 1993). It hybridizes with Eastern redcedar (*J. virginiana* L.) where the species overlap, with gene flow in an easterly direction. It also hybridizes with creeping juniper to form the hybrid *J.* x *fassettii*. Van Haverbeke and King (1990) found significant genotype-environment interaction, but not in northern sources, supporting broad transferability of populations in the Great Plains region. Adams and Demeke (1993) found three distinct groups of *J. scopulorum* in western North America, with strong differentiation among populations from Vancouver Island, and some east-west differentiation in Canadian sources, ultimately leading to splitting of *J. maritima* from *J. scopulorum* (Adams 2007).

Rocky Mountain juniper is scattered on suitable xeric sites from northwestern B.C. throughout the Rocky Mountain and Great Basin regions to Texas and New Mexico. Detailed range maps and genetic data are lacking. It often grows in dense clumps and has merchantable status in the southwestern U.S. In Alberta it is only minimally impacted by development. It is well represented within the national and provincial protected areas in the Rocky Mountain Natural Region, with a few populations the Foothills Parkland represented at Lundbreck Falls and Oldman Reservoir Public Recreation Areas; Black Creek and OH Ranch Heritage Rangelands; and Sheep Creek Provincial Park, and Bluerock and Bob Creek Wildland Provincial Parks; however only a few of those areas probably support 5,000 unrelated genotypes.

Scouler's Willow (*Salix scouleriana* Barr. ex Hook.) Salicaceae

W. Mark and J. Reimer

A. Schneider

Species Characteristics Scouler's willow is a large shrub or small tree, often crooked in stature, growing up to 20 metres high on the best sites in its range (about 12 metres in Alberta). It has grey, smooth bark that becomes fissured in older stems and develops the diamond-shaped scars characteristic of some willow species. The greenish-brown twigs are hairy when young. The leaves, five to 12 centimetres long, are characteristically oblanceolate to obovate, and narrow abruptly to an obtuse or rounded tip. Rust-coloured hairs are typically present on the undersides of the leaves in addition to white hairs and may be abundant enough to give a brownish patina to the lower leaf surface. The stipules vary in size from obscurely minute to up to ten millimetres long, with longer stipules on vigorous shoots.

Pollen and seeds are produced on different trees in catkins containing many flowers. The catkins appear before or at the time of leaf flushing and lack stalks; pollen catkins are two to four centimetres long and bear male flowers with two stamens. Seed catkins are two to six centimetres long, developing into capsules five to eight millimetres long and densely grey-hairy. Scouler's willow resembles a number of other willows but in the field in Alberta, it is perhaps most likely to be confused with plane-leaved willow, *S. planifolia*.

General Ecology Scouler's willow occurs throughout western North America, from Alaska and Yukon south as far as New Mexico and, in Canada, as far east as Manitoba. In Alberta, it is most frequently encountered at relatively low elevations in the Rocky Mountains and in northern boreal habitats. This species is associated with dry coniferous woods, floodplains, bogs, and sandy beaches or sand dunes.

Scouler's willow has an ecologically important role, providing food and cover for insects and birds, lowering stream temperatures by providing shade, and stabilizing riparian sediments as well as loose soils in upland and disturbed sites. Common associates are aspen (*Populus tremuloides*), balsam poplar (*P. balsamifera*), paper birch (*Betula papyrifera*), and on upland sites Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* var. *glauca*), lodgepole pine (*Pinus contorta* var. *latifolia*) and Engelmann spruce (*Picea engelmannii*).   The species is easily killed by wildfire.

Regeneration   Scouler's willow reproduces by seed and by root sprouting and by branch fragment rooting. Seeds require light to germinate and it is shade-intolerant throughout its life cycle. It can be easily propagated from stem cuttings for reclamation. Pollination is primarily by insects.

Evolution and Genetics   Scouler's willow is one of many willow species but only two are found as trees in Alberta. No genetic studies have been done to date on this species. Scouler's willow is extremely common and widely distributed across western North America from Alaska to the southern limit of the U.S., absent from the arid prairies. It prefers riparian habitats but grows in many types of forests, wetlands, and disturbed sites. Scouler's willow sprouts readily and produces abundant seed early. More than 5,000 individuals are likely needed to conserve 5,000 unique genotypes because of its occasional clonal habit. This species is very unlikely to have any conservation gaps, but verification in protected areas, particularly in Foothills Parkland and Peace River Parkland natural subregions is suggested. Alberta Biodiversity Monitoring Institute models show this species present across much of Alberta, in highly variable densities but most frequently between 25 and 40 percent cover.

Subalpine Fir (*Abies lasiocarpa* Hook. Nutt.) Pinaceae



Government of Alberta L. Allen

Species Characteristics Subalpine fir is a medium-sized to large evergreen tree growing to 30 metres high, living over 500 years (Luckman 2003). The narrow conical crown tapers to a spire-like top. In young trees the bark is smooth and grey with raised resin blisters, becoming grey-brown, furrowed and scaly with age. The flat needles are one to three centimetres long, one to two millimetres wide, with rounded or notched tips. Needles are arranged singly and spirally around the twig although they appear two-ranked on lower branches and both surfaces bear three to six lines of white stomata. Pollen and seed cones grow on the same tree. The dark purple-grey barrel-shaped seed cones stand upright and break up while on the tree, leaving a persistent upright cone axis for several years.

General Ecology Subalpine fir grows in continental subalpine forests, extending from the Yukon to New Mexico, with extensive populations in British Columbia and Alberta. It grows at elevations of 600 to 3,600 metres in the Rocky Mountains; in Canada it is most abundant above 1,500 metres. It grows on a wide variety of soil types, but because of its low tolerance to heat and its high transpiration rate, this species is restricted to cool, humid sites. It is a pioneer in extreme sites but occurs most frequently as a co-dominant with Engelmann spruce (*Picea engelmannii*), forming a long-lived seral forest or self-perpetuating mature stand. Subalpine fir is a common, widespread species within its habitat and a prolific reproducer, growing in mixed stands with numerous associates. At timberline, this spruce-fir community often grows as a dense krummholz thicket one to two metres high.

By providing tree cover, this slow-growing fir is important in moderating streamflow and snowmelt at headwaters of watersheds, facilitating treeline ecotone dynamics, stabilizing fragile soils in mountain parklands, and provides habitat for many birds and small mammals. It is a major component of the mountain ecosystems that provide recreational opportunities and fine views.

Regeneration Subalpine fir reproduces mainly by seed. Vegetative reproduction by layering is common on severe sites at timberline and on talus slopes. Open-growing trees may produce cones at 20 years of age but under closed-forest conditions, maximum seed production usually occurs at 150 to 200 years in dominant trees. Years of heavy seed production alternate with years of no or light production. Seed ripens from mid-September to late October and is dispersed by wind from October to December and eaten by small mammals and birds. Although subalpine fir grows under a variety of natural light intensities, establishment and early survival appear to be assisted by shade because, although tolerant of high solar radiation, seedlings are susceptible to heat girdling and drought. It is most competitive with other conifers in conditions with less than 50 percent shade.

Evolution and Genetics Subalpine fir is one of ten or 11 species of *Abies* native to North America. The number of species recognized varies by taxonomic authority. For Alberta, opinions range from regarding all native *Abies* species as variants of balsam fir (*A. balsamea*) to granting species status to the taxon distributed in western Alberta as subalpine fir (*A. lasiocarpa* or *A. balsamea ssp*. *lasiocarpa*). Some treatments consider *A. lasiocarpa* as a more coastal species that does not occur in Alberta (Flora of North America Editorial Committee 1993). Subalpine fir is sometimes treated as Rocky Mountain subalpine fir (*A.bifolia* or *A. lasiocarpa* ssp. *bifolia*). Trees in many locations have characteristics intermediate between balsam fir and subalpine fir, which suggests hybridization occurs where they grow together (Frank 1990), but no genotypic confirmation exists. This report treats populations from higher elevations in western Alberta as subalpine fir and populations as hybrids in areas where the distribution of balsam fir overlaps it in the vicinity of Lesser Slave Lake and the Athabasca River in north-central Alberta.

Northern populations of subalpine fir have high genetic variation, with very low variation between populations (Shea 1990; Sønstebø andTollefsrud 2012). Grant and Mitton (1977) observed genetic and adaptive clines with elevation. Ettl and Peterson (1995) and Peterson et al. (2002) found no association between performance and site climate within regions, but there were adaptive differences between regions. Genotypic studies also indicated a higher tolerance of inbreeding or selfing in this species than most conifers (Shea 1987).

It is considered poor quality for lumber so is often left on site. It is extremely well protected in the Rocky Mountain Natural Region in the national and provincial protected areas network. In the Upper Foothills, viable populations are represented in the Brazeau Canyon Wildland Provincial Park, Wapiabi Provincial Recreation Area, and Marshybank Ecological Reserve. No conservation gaps are identified.

Subalpine larch (*Larix lyallii* Parl.) Pinaceae

D. Vujnovic

J.D. Johnson

D. McIntyre

Species Characteristics Subalpine larch is a slow-growing, long-lived tree, often reaching 500 years old. In the timberline environments where it grows, it can grow to 12 to 25 metres, with a diameter of exceeding 50 centimetres. It is a slender, irregularly branched tree with a sparse, ragged crown. The bark is smooth and grey when young, furrowed and flaking into red- or purple-brown plates in age.

The bluish-green needles are four to five centimetres long and less than one millimetre wide, in tufts of 30 to 40 on numerous distinctive short or spur shoots, or singly along long shoots. In fall needles of mature trees turn golden and are shed annually; seedlings may retain needles for up to two years. Pollen and seed cones grow on the same tree at the ends of short shoots. Seed cones have thin, persistent scales subtended by awn-tipped bracts. The densely hairy twigs of subalpine larch distinguish it from the similar western larch, (*L. occidentalis*), which typically occurs at lower altitudes (up to 1,500 metres).

General Ecology Subalpine larch has a restricted distribution in the mountains of southwestern Alberta, southern British Columbia, Idaho, Montana and Washington. It usually occurs on rocky or gravelly soils on mountain slopes from 1,500 to 2,800 metres, where it forms open, pure stands above the limit of other conifers as long as there is sufficient growing season moisture. In Alberta, this species is restricted to the Rocky Mountains south of the Red Deer River. It may be mixed with subalpine fir (*Abies lasiocarpa*), Engelmann spruce (*Picea engelmannii*), and whitebark pine (*Pinus albicaulis*).

Subalpine larch is adapted to a cold, continental climate with a short growing season. Its resistance to winter desiccation is aided by its deciduous habit and woody, protected buds. Although it may be stunted due to harsh growing conditions, it does not adopt a krummholz form. The flexible trunks of young trees flattened by avalanches straighten out when the snow melts. Subalpine larch is shade-intolerant, moisture-loving and adapted to cold temperatures; it grows best in high cirques and at the bases of talus slopes where seepage maintains a moist substrate. It is important for watershed protection, wildlife habitat (blue grouse (*Dendragapus obscurus*) eat its needles) and aesthetics.

Regeneration Reproduction is almost exclusively by seed, although seedlings are not common. The erect, purplish-brown seed cones mature in the first season but remain on the tree for several years. Large seed crops are infrequent, and trees produce little seed until they reach at least 80 years old. Winged seeds are dispersed by wind. Low seed counts per cone and low seed viability means successful germination is rare, requiring a moist, mineral soil substrate.

Evolution and Genetics Of the ten species of larch, three grow in Alberta: tamarack, western larch, and subalpine larch. Phylogenetically, tamarack is considered to belong to a different group of larches than the other two North American species. Where the distributions of subalpine larch and western larch overlap, natural hybrids have been found and the two species can be artificially crossed (Carlson 1994; Arno et al. 1995).

Genetic diversity in the species is low (Khasa et al. 2006); genomic marker studies have revealed two population groups in this species range-wide (M. Vance and P. von Aderkas, in prep.). Its narrow ecological niche, long generation time, and low diversity pose long-term threats to its viability, particularly in light of climate change

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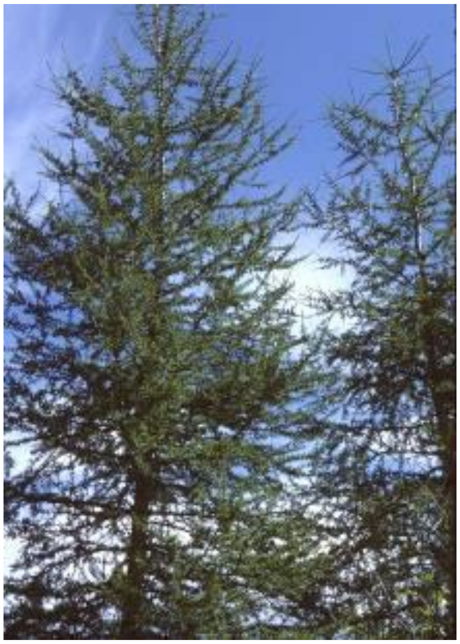
Tamarack (*Larix laricina* (Du Roi) K. Koch) Pinaceae



L. Allen A.J. Gould

Species Characteristics Tamarack is a medium-sized tree rarely older than 150 years. The bark is rough, scaly, and reddish-brown. Needles are deciduous, one to two-and-a-half centimetres long, three-angled and mostly in clusters on dwarf spur shoots. Seed and pollen cones grow on the same tree. Seed cones are one to two-and-a-half centimetres long with bracts shorter than cone scales. Related species in Alberta are western larch (*L. occidentalis*) and subalpine larch (*L. lyallii*). Hybrids are not reported.

General Ecology Tamarack ranges from Labrador to central Alaska, but is absent along the border between Alaska and the Yukon. Tamarack is a common species of boreal lowlands in Alberta where it is associated with extensive areas of poorly drained peatlands, where it can occur as open or closed stands, commonly in association with black spruce (*Picea mariana*). It occupies wetlands and their margins in the foothills as far south as the Red Deer River drainage. The best developed and most extensive stands are in nutrient rich fens and wetlands adjacent to major drainages including the Athabasca, Peace and Hay Rivers. Peripheral populations occur along the parkland boundary with boreal and foothills forests. Outlier stands are reported near Canmore.

Tamarack is a species of early succession. It is very shade-intolerant. Where established seedlings have adequate light and moisture, growth is rapid.

Tamarack is vulnerable to epidemics of the larch sawfly (*Pristiphora erichsonii*), which causes severe defoliation and may recur for several years resulting in high mortality and growth reductions. With thin bark and shallow roots, the species, particularly seedlings, is highly vulnerable to fire, flooding and drought.

Regeneration Tamarack reproduces almost entirely by seed. Branches covered with moss may develop roots, and shoots developed from roots have been reported; layering is more common further north (Elliott 1979) and also occurs along the western limit of the range. Seed production begins around age 15 but is not abundant until much later. Wind disperses the tiny seeds, which sprout abundantly on moist mineral seedbeds with light shade.

Evolution and Genetics Of the ten species of larch, only three grow in Alberta and North America: tamarack, western larch, and subalpine larch. Tamarack belongs to a different taxonomic group of larches than the other two North American species. There is little opportunity for tamarack to naturally hybridize with other native larches because of differences in habitat and no natural hybrids have been reported. Tamarack has been artificially crossed with other larch species but seed yields have been low.

Fowler et al. (1995) found early height was negatively correlated with more northern and western sources. Joyce (1988) found steep clines for cold hardiness and height, with genetic variation varying among test sites. Genetic load was determined to be high for tamarack (Fowler et al. 1995), while Knowles et al. (1987) determined multilocus outcrossing rates to be very low for a conifer (0.73), indicating high levels of inbreeding including selfing. They determined tamarack has high gene flow and low population differentiation. Differences in height growth are apparent in provenance trials in Alberta but relationships with climatic and geographic variables were weak (Government of Alberta, unpubl. data). Tamarack is rarely planted for reforestation, but a small tree improvement archive exists.

Tamarack has a broad boreal to sub-boreal distribution in poorly drained forests, where it is most often found with black spruce, balsam poplar, and paper birch, but does occur in pure stands. Range-wide studies have shown clinal variation with no unique ecotypes (Johnston et al. 1990). It is not a target species for harvest in Alberta, although it is harvested from time to time with associate species. Boggy tamarack stands are frequently excluded from harvest due to sensitive soils and poor drainage. It represented in the protected areas network across northern Alberta, including Wood Buffalo National Park, and is extensively informally retained on the unprotected landbase, averaging ten to 40 percent cover in most polygons. No conservation gaps are identified.

Water Birch (*Betula occidentalis* Hook.) Betulaceae

L. Allen

Species Characteristics A tall shrub or small tree growing up to 12 metres high and 30 centimetres in diameter, water birch has a characteristically smooth, shiny, reddish-brown bark with long lenticels that does not peel readily. The twigs are more or less hairy but invariably bear prominent warty resinous glands. Leaves are two to five centimetres long, broadly ovate to rhombic in shape, and irregularly doubly serrate; their undersides are covered with minute resin glands.

Water birch bears male flowers in elongate catkins (six centimetres long at anthesis) and fruits in shorter catkins (two to three centimetres long at maturity) on the same tree. The fruits (samaras) are borne in the axils of three-pronged scales, which have hairy margins. Although water birch has a substantially different appearance from Alaska birch (*B. neoalaskana* Sarg.) and paper birch (*B. papyrifera* Marsh.), it hybridizes with both species creating trees with characteristics intermediate between the parents.

General Ecology Water birch is widely distributed across western North America, from Alaska across the Great Plains, as east to northwestern Ontario, and south to California and Colorado. It occurs along river and stream banks, lakeshores, and in wet swales. It may form pure thickets or be mixed with willows (*Salix* spp.), alders (*Alnus* spp.) and poplars (*Populus* spp.). In Alberta, it is particularly common in the mountains, although it also occurs in moist depressions in the prairies.

Regeneration Abundant winged fruits are dispersed by wind and water when the fruiting catkins shatter in autumn.

Evolution and Genetics The birches are taxonomically complex in North America with up 16 recognized species and two subspecies, and many varieties and hybrids that are not really possible to accurately distinguish based on morphology (Furlow 1997; Schenk et al. 2008; Appendix 2). Alberta has six native species but only Alaska, white and water birch are classified as trees. Natural hybrids of Alaska birch with white and water birch, as well as with dwarf birch have been reported although the accepted taxonomic status is not resolved; zones containing hybrid swarms of varying degrees of introgression are common (Schenk et al. 2008).

Water birch is a morphologically variable species across its wide range. Moss (1983) recognized three varieties in Alberta based on whether the fruiting catkins are single or paired and on the pubescence and glandulosity of the twigs; current taxonomy accepts only the species with no subdivisions. Populations have an average amount of genetic diversity compared to other tree species with similar life history traits; gene flow is high, resulting in very little differentiation between populations and little structuring within populations (Williams and Arnold 2001). Most low frequency alleles are absent in populations that have recolonized following glaciation.

Water birch has an extensive range composed of disjunct patches in suitable habitat from B.C. throughout the U.S. west and midwest, extending to Manitoba. This non-merchantable species and its hybrids are considered adequately represented in areas excluding from the harvesting landbase, national and provincial protected areas in the Rocky Mountain and central and southern Parkland Natural Regions, and in riparian buffers and areas that would be retained in their natural state for range use. No conservation gaps are identified.

Western Hemlock (*Tsuga heterophylla* (Raf.) Sarg.) Pinaceae

L. Brubaker

D. Baron

H.-C. Speel

Species Characteristics Western hemlock is a tall evergreen conifer, with a narrow crown, reaching heights of about 50 metres and with a trunk diameter of up to two metres. It can live for 500 or more years. In Alberta, however, it rarely becomes a medium-sized tree. A distinctive feature is its drooping leading shoot. The bark of young trees is grey to brown and smooth, and becomes scaly and fissured with age. The flat leaves with rounded tips are borne singly in a two-ranked arrangement on stalk-like projections that persist after the leaves fall. They are one to two centimetres long in varying lengths as indicated by its name, and the lower surface is glaucous with two ill-defined bands of stomata.

Pollen and seed cones are borne on the same tree, although the former are clustered around the base of the leaves and the latter are terminal on the lateral shoots. Seed cones are one-and-a-half to two-and-a-half centimetres long with cone scales that are rounded and golden brown at maturity.

General Ecology Western hemlock is a tree of moist climates. Within both coastal and northern Rocky Mountain ranges, it has an altitudinal spread from sea level to about 1,500 metres. Along the coast it extends from Alaska south to central California, and on the west side of the Rocky Mountain ranges from British Columbia to Montana, with isolated occurrences in Alberta. It will tolerate a variety of soils, but grows best on moist soils with a moderately thick upper layer enriched with organic material. It is both a pioneer and climax species, growing in pure stands or mixed with other conifers, where it is often the dominant species. In Alberta western hemlock occurs in forests of subalpine fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea engelmannii*), as well as lodgepole pine (*Pinus contorta* var. *latifolia*) at 1,300 to 1,500 metres (ACIMS 2018). It provides important browse for deer and elk.

Regeneration Regeneration is mainly by wind-dispersed seed although layering can occur and cuttings can be rooted easily. Full seed production occurs in trees 25 to 30 years old and mast crops are produced at intervals of two to eight years. Seeds ripen by mid to late September and, if the weather is very wet, seeds may be retained by closing of the cone scales. Western hemlock is a prolific seed producer although often seed viability is below 50 percent. Seeds remain viable only during the first growing season after release. The small seeds have wings that aid in wind dispersal, but most seed falls near the parent tree.

Western hemlock is very tolerant of shade. Its seedlings establish well and can grow rapidly in suitable conditions under both open and closed canopies. Decaying logs make good, moist, nutrient-rich seedbeds, sometimes leading to lines of trees. Seedlings are extremely abundant in the understory.

Evolution and Genetics Western hemlock is the only one of three North American hemlock species found in Alberta. Although genetic variation has not been studied in Alberta, the species, especially in its coastal distribution, has abundant genetic variation among and within populations, with populations performing best when they are transferred approximately one to two degrees of latitude north. Several programs of genetic improvement for growth rate and form are developed in the Pacific Northwest.

Western Larch (*Larix occidentalis* Nutt.) Pinaceae

A.J. Gould

A.J. Gould

Government of Alberta

Species Characteristics Western larch is a long-lived tree and the largest larch species in Canada, occasionally more than 50 metres tall. Bark is furrowed on older trees. Leaves are yellowish-green, flatly three-angled and shed annually in fall. Seed and pollen cones grow on the same tree. Mature seed cones are two to five centimetres long with bracts generally not much larger than cone scales. Similar species are tamarack (*L. laricina*) and subalpine larch (*L. lyallii*).

General Ecology Western larch grows in the Rocky Mountains and eastern slopes of the Cascade Mountains between 43° and 52°N, from 1,200 metres in the north to 2,100 metres elevation in the southern part of the range. In Alberta, the species is at the margins of its range, restricted to the upper montane and lower subalpine forests of the Crowsnest, Waterton and Kananaskis areas and is relatively rare, ranked S2. Population density ranges from thinly scattered individuals to mixed stands approximately half composed of larch.

Western larch is a disturbance-maintained species in fire-dependent stands, and a seral species associated with lodgepole pine (*Pinus contorta* var*. latifolia*), Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* var. *glauca*), Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*). Western larch is shade intolerant and grows best on deep, porous soils on cooler exposures, and requires moisture during the growing season. On good sites it can outgrow most associates.

Regeneration Western larch reproduces by seed only. It can make seeds before age ten, but wild stands reach full fecundity after 40 to 50 years. The small seed has a large wing and can be carried far by wind. Seed crops are periodic, masting approximately every five years. Seed cones have low proportions of filled seed (Owens and Molder 1979; Owens et al. 1994; Webber and Ross 1995), wild seed is frequently predated (Stoehr 2000). Ashes or mineral soil are effective seedbeds. Few seedlings survive on south and west slopes in full sun, although stands may be found on all exposures at mid- to high elevations. Fully shaded seedlings, however, grow poorly and shade-intolerance is strong.

Evolution and Genetics Of the ten species of larch, three grow in Alberta: tamarack, western larch, and subalpine larch. Tamarack is in a different taxonomic group of larches than the other two species. Where the distributions of subalpine and western larches overlap, natural hybrids have been found and the two species can be artificially crossed (Carlson 1994; Arno et al. 1995).

Western larch tolerates moderate levels of inbreeding (El-Kassaby and Jaquish 1996). Populations have moderate to high gene flow (Fins and Seeb 1986), but the disjunct Alberta sources are likely more inbred and genetically distinct than in the core of the species' range (El-Kassaby and Jaquish 1997). Genetic variation associated with geography has been shown although rates of genetic change along environmental gradients are gentler than for many tree species. These patterns reflect a balancing of growth potential with cold hardiness. Western larch exhibits significant population and family differentiation in growth, cold hardiness, and phenology. There is a genetic archive in Alberta but the species is not planted operationally.

Western larch is Priority 1: rare, scattered, very uncommon in Alberta at the eastern and climatically continental limit of its more contiguous range in B.C. and the U.S. Bioclimatic envelope models indicate it will retain a marginal presence in Alberta or be extirpated in the coming decades (Rehfeldt and Jaquish 2010), given its affinity for growing site moisture, which will decline with reduced snowpack and increased summer drought. In situ conservation alone will not counter this trend. Populations, which may have fewer than 5000 mature trees, are represented in Waterton Lakes National Park and the Castle Wildland Provincial Park. Western larch is reserved from harvest on Crown land outside of parks; it is not planted or used in restoration in Alberta. Confirmation of population size in protected areas is recommended.

Western Redcedar (*Thuja plicata* Donn ex D. Don) Cupressaceae

C. Crell

A.J. Gould

Species Characteristics Western redcedar is a coniferous tree that can live for 1,000 years, occasionally 2,500. Generally a large tree it is at the extreme eastern edge of its distribution in Alberta, ranging from a shrub to a small tree. The crown is conical, with arching branches and pendulous branchlets. Young trees have reddish- or grayish-brown smooth bark becoming fibrous with age. Leaves are opposite, in two types: four to five millimetre long awl-shaped leaves on larger branchlets or juvenile trees, and one to two millimetre long crowded and appressed scale leaves on flattened, lateral branchlets. Leaves are glossy-green on top, with white stomata beneath that give a silvery appearance. The reddish pollen cones are one to three millimetres long and green, turning brown. Seed cones are ten to 14 millimetres long with four to ten paired scales. Pollen and seed cones are produced on the same tree, pollen generally on the lower branches and the seed cones towards the top. There are no similar species in Alberta. True cedars (*Cedrus* spp.) are classified in the Pinaceae, native to the Mediterranean and western Himalayas.

General Ecology This species has a coastal range from southeast Alaska to northwest California, and an interior range along the Rocky Mountains from British Columbia and Alberta to

Idaho and Montana, with scattered stands between the two in southern British Columbia. Most Alberta records are from the Crowsnest Pass, although scattered occurrences are reported north of Willmore Wilderness Park. Western redcedar grows mostly in moist sites, in mixed coniferous forests rather than in pure stands, at altitudes of sea level to 2,200 metres. Above 1,500 metres and in harsh environments the form becomes more shrubby. It will grow on a wide variety of soils, from moist alluvial to rich dry soils, and including sites low in nutrients such as sphagnum bogs.

Western redcedar thrives in all stages of succession as its seeds establish on disturbed areas, but it is also found in mature and climax forests due to its shade tolerance and capacity for vegetative reproduction. Western redcedar is typically associated with western hemlock (*Tsuga heterophylla*), Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* var. *glauca*), and at higher elevations with western larch (*Larix occidentalis*) and Engelmann spruce (*Picea engelmannii*), in Alberta. it typically occurs with Engelmann spruce or white spruce (*Picea glauca*) and lodgepole pine (*Pinus contorta* var. *latifolia*) (ACIMS 2018). The heartwood of western redcedar is extremely resistant to decay, and its wood is used for diverse exterior products. Cedar leaf oil is used in many compounds. Indigenous North Americans used the tree extensively for the construction of lodges, canoes, clothing, baskets, waterproof implements and clothing, weaving, nets, carvings, poles, distilling essential oils, and many other uses. Growth is slower than for most associated tree species in unmanaged forests; it is not a commercial species in Alberta

Regeneration   Western redcedar reproduces mainly by seed and occasionally by layering, rooting of fallen branches and branches growing from fallen trees. Cones are produced after age ten and every other year thereafter, but under have been induced by age two. Anthesis occurs in May or June in interior stands and seed matures in October to November in the same year. The small, two-winged seeds are disseminated by wind. There is little loss of seed due to predation, but post-germination seedling mortality can be high. In the northern Rocky Mountains, natural regeneration occurs best on slopes with western and northerly aspects with partial shade.

Evolution and Genetics   Two species of *Thuja* occur in North America, but western redcedar is the only one in Alberta. The species is highly tolerant of selfing (self-fertilization) and mating among closely related individuals, which can be used for testing and breeding. Western redcedar has likely recolonized its current range from a single refugium. Trees in the Allison Creek valley may be the eastermost distribution (MacIntyre 2005).

Genotypic and adaptive studies show high genetic variation in western redcedar populations (O'Connell et al. 2008) that was not detected in studies using earlier markers (Yeh 1988). There is abundant additive and non-additive variation for morphological (Grossnickle and Russell 2010), growth, and biochemical traits that is being exploited in breeding programs in British Columbia (Russell et al. 2003) for growth, form, wood quality, and resistance to deer browse (Russell and Yanchuk 2012).

Western White Pine (*Pinus monticola* Dougl. ex D. Don) Pinaceae

A.J. Gould

C. Crell

Species Characteristics Western white pine is a large tree of western North America; in Alberta it is limited to a few scattered trees in the southwest corner. This evergreen conifer is a slender, columnar tree with well-spaced whorls of relatively short, spreading branches borne on the upper two-thirds of the trunk; open-grown trees have more rounded crowns. Young bark is grey and smooth, becoming furrowed and scaly-plated in older trees. The leaves are in bundles of five, enclosed by sheaths of basal scales, which fall off in the first year of growth. The leaves are five to 15 millimetres long, seven-tenths to one millimetre wide and bluish-green with lines of white stomata on the undersides.

Both pollen and seed cones are produced on the same individual. The yellow catkin-like pollen cones develop in clusters at the base of new shoots, in the mid to lower parts of the crown. Seed cones are in whorls at the tip of new shoots mostly in the upper half of the crown. The ripe cones are cylindrical, ten to 25 centimetres, creamy brown. Two other five-needled pines occur within the range of western white pine in western Canada: limber pine (*P. flexilis*) and whitebark pine (*P. albicaulis*).

General Ecology Western white pine has a coastal range from southern British Columbia to the Sierra Nevada and an interior range from British Columbia and Alberta through Idaho, western Montana and northeastern Oregon. It has a wide elevational range, from sea level to 3,000 metres; in the Rocky Mountains it occurs between 500 and 1,800 metres where it favours valley bottoms and lower north-facing slopes in steep terrain. It grows on a variety of soils in diverse habitats; like most pines it is characteristic of well-drained soils but grows best on deep, richer soils. Habitats range from open, rocky mountain slopes to lowland coastal bogs. It is a seral as well as a disturbance-maintained climax species that is usually found in mixed stands with other conifers. It once dominated the intermountain region and some coastal areas with extensive pure stands but experienced a precipitous decline during the previous century following the introduction of the fungal pathogen that causes white pine blister rust. A relatively shade-intolerant tree, it grows rapidly and becomes dominant in a stand following fire or forest management.

The species is prized commercially: the soft, light, non-resinous wood with small knots and large clear sections is used for a variety of purposes including structural lumber, shipworks, veneer, matches, and handicrafts.

Regeneration Regeneration is exclusively by seed. Trees aged from seven to 20 years produce predominantly female cones, with heavy seed production occurring after about 70 years. It takes two years from the initiation of cones to the production of ripe seeds, with pollination taking place in the spring and seed release in fall one year later.

Seed dispersal is by wind and seed-eating animals and birds. The seeds require one to four months of cool, moist conditions before they will germinate. In sheltered sites the seedlings grow best in partial or no shade, and once established thrive best in full sunlight.

Evolution and Genetics Of the five pine species in Alberta, western white pine is most closely related to limber pine. Natural hybrids with other pine species native to Alberta have not been reported although western white pine has been crossed artificially with close relatives. All five-needle pines are cross-compatible for grafting.

In contrast to most tree species, western white pine shows little genetic differentiation among populations and is adaptated to a wide range of conditions due to its high phenotypic plasticity. Differences in cold hardiness, growth phenology, and susceptibility to white pine blister rust have been found between coastal and interior populations in British Columbia. There are numerous successful operational tree improvement programs for this species in the Pacific Northwest, all of which incorporate resistance to white pine blister rust.

Western Yew (*Taxus brevifolia* Nutt.) Taxaceae


A.J. Gould

Species Characteristics Western yew is an evergreen coniferous tree or shrub, reaching usually less than 15 metres tall with a trunk diameter of up to 60 centimetres. It is slow-growing but may live for several hundred years. The crown is open-conical and irregular, sometimes with a central straight stem and sometimes with a widely branched crooked open form. Trunks of older trees may be fluted and twisted. The thin, reddish-purple bark is smooth in youth but scaly in age and mossy when growing in moist habitats. The leaves, which are linear and flattened, with a pointed but soft tip, are from one to three centimetres long. Green above, they are pale green on the lower surface where two broad bands of stomata are located. They are inserted in two ranks along characteristically green twigs, older twigs turning brown.

The pollen cones are globose with four to 12 scales, and are borne in profusion on the undersides of twigs on male trees. Seed cones are fewer and also occur on the undersides of twigs, but on female trees. Pollination is by wind. Each cone has a single seed that is enveloped in a red, fleshy aril with an exposed seed, the familiar yew "berry." The other yew species in Canada, Canada yew (*T. canadensis*), extends only as far west as southeastern Manitoba.

General Ecology Western yew has two distinct distributions: a coastal one ranging from Alaska to California, and an interior one along the western slopes of the Rocky Mountains including southeastern British Columbia and extending into Idaho and Montana. In the east it is usually a scattered, minor to rare, understory tree of conifer or hardwood forests. In dry areas it is confined to stream edges and the lower slopes of ravines, but in humid regions it prefers slopes and ridge tops. In Alberta, it is known from only one location, in Waterton Lakes National Park, where it occurs with Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*). This is in the area that was burnt during the 2017 Kenow Mountain wildfire, so the population may no longer be extant.

The reddish-purple wood is hard and durable and has a variety of specialty uses for cabinetmaking, inlays, marquetry, crafts, bows and paddles. All parts of the plant are toxic (Wilson et al. 2001) except for the aril fruit. Natural populations of western yew were severely impacted during the 1980s and 1990s when the species was exploited for taxol, a treatment for breast cancer. These impacts declined after a synthetic form was developed.

Regeneration Western yew reproduces mainly by seed but can regenerate vegetatively by stump sprouts and by layering. Seed production can be prolific. Birds are particularly attracted to the fleshy arils of the seeds. Both birds and rodents are responsible for seed dispersal. Rodents and some bird species cache the seeds and disperse them in droppings, leading to clusters and groupings of seedlings. Seedlings germinate best in forest litter, and some are capable of germinating in the second spring after sowing. Western yew is shade-tolerant but also does well in full sunlight.

Evolution and Genetics Genetic studies indicated low genetic diversity within populations, and moderate differentiation between populations (Wheeler et al. 1995), as well as significant variation in taxol content among populations but with no clear geographic trends. These patterns were attributed to the animal dispersal of limited numbers of individuals, ability to vegetatively reproduce, and low population density. Taxol production was also found to vary among individual plants, seasonally, and with the plant tissue selected (Wheeler et al. 1992).

White Spruce (*Picea glauca* (Moench) Voss) Pinaceae

L. Allen

Species Characteristics White spruce is a large, narrow-crowned tree with grey, scaly bark and twigs that are usually hairless. Green to blue-green, the sharp-pointed leaves are four-sided and spirally arranged around twigs. Leaves often are covered with a whitish wax with a strong aroma when crushed. Pollen and seed cones are produced on the same tree. Seed cones are three to eight centimetres long with reddish-brown cone scales that have smooth, rounded edges. Similar species are black spruce (*P. mariana*) and Engelmann spruce (*P. engelmannii*).

General Ecology White spruce is a major component of the North American boreal forest from the northern limit of tree growth in the west, to 45°N in the east. In Alberta, the southern limit of the species is north of Lloydminster, then southwest, extending along the Battle, Red Deer, and Bow Rivers, and west from Calgary. A major isolated relict population is in the Cypress Hills.

The species is common in mixtures with aspen (*Populus tremuloides*), balsam poplar (*P. balsamifera*), black spruce (*Picea mariana*), lodgepole pine (*Pinus contorta* var. *latifolia*), and to a lesser extent paper birch (*Betula papyrifera*) and Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) in early to mid-successional stands of boreal, foothills and montane forests. In mid- to late-succession, it forms pure stands or occurs with black spruce and balsam fir. With full light and minimal competition, it grows rapidly. In the Parklands Natural Region small populations occur, typically on north facing slopes on moist sites along its southern and eastern limits. White spruce occupies a wide range of soils and can behave as a pioneer species in disturbed habitats or as a climax species following aspen succession. It provides thermal wildlife shelter during winter and its seeds are an important source of food for many species of birds and small mammals.

Regeneration White spruce reproduces naturally only by seed and dispersal is mainly by wind. Good cone production generally begins around 30 years with substantial crops at two to six year intervals, less often in colder climates. Seedbed moisture is the most important factor in establishment from seed although competition also limits success. White spruce is moderately shade tolerant, frequently growing under aspen canopies.

Evolution and Genetic Variation Five spruce species are native to Canada, and three to Alberta: Engelmann spruce, black spruce and white spruce. Hybrids with Engelmann spruce are common, and many genetic markers are available to quantify introgression and other genetic attributes as morphology is not reliable (Rajora and Dancik 2000; de la Torre et al. 2014). With increasing elevation in western Alberta, the proportion of Engelmann spruce increases. Hybridization with black spruce does not occur (Nkongolo et al. 2005).

Genetic variation in white spruce has been extensively studied due to its commercial importance and broad distribution. There are numerous tree improvement programs in Alberta and elsewhere. The species has average levels of genetic diversity and population differentiation (Liepe et al. 2014; Gray et al 2016a). Clinal patterns of adaptive and genotypic traits are the norm, with some anomalies in isolated populations like Cypress Hills. Sources from parts of Manitoba and eastern Canada have shown good survival and vigour in Alberta, sometimes better than local sources. White spruce has been the subject of thousands of studies on fecundity, reproduction, wood traits, physiology, pest and pathogen resistance, and stand dynamics.

White spruce is one of the most common and abundant species in the province, and is a commercially managed timber species. In addition to the many populations overlapping provincial and national protected areas, it is also very widespread in buffers and areas excluded from the harvesting land base. It dominates most polygons it is found in, both within and outside protected areas. Participants in approved tree improvement Controlled Parentage Programs are working to establish gene conservation areas in applicable locations. No conservation gaps are identified.

Whitebark Pine (*Pinus albicaulis* Engelm.) Pinaceae



D. Vujnovic

Species Characteristics Whitebark pine is a small to large evergreen tree restricted to high elevations. It is often shrubby or multi-stemmed but may be single-stemmed, reaching 30 metres tall. Stands and trees may persist for 500 to 1,000 years. The bark of young trees is smooth and light grey to white, turning darker and platy. Needles grow in bundles of five and are five to ten centimetres long.

Whitebark pine is the only North American pine whose cones cannot open, even following fire, at maturity and whose seeds are wingless. Pollen and seed cones grow on the same tree. Seed cones are oblong to round, five to ten centimetres long, purple turning brown with age, at the ends of upswept branches in the upper crown. Pollen cones are yellowish turning red when mature, found on newer shoots around the canopy, up to one-and-a-half centimetres long. Limber pine (*P. flexilis*) is a similar species that usually grows at lower elevations. The species are best distinguished by cones and do not hybridize.

General Ecology Whitebark pine has a coastal and an interior distribution, with some intermediate populations. Spanning from 41° to 55°N it grows from glaciofluvial montane fans to treeline. In the northern part of its range, whitebark pine often occurs in disjunct populations on ridges and talus slopes up to approximately 2,500 metres and down to 900 metres; in the southern part of its range it forms continuous pure forests on gentler topography. In Alberta, whitebark pine extends from Waterton Lakes National Park to Kakwa Wildland Provincial Park, in the Subalpine-Alpine Natural Subregion transition.

Whitebark pine is both a pioneer and climax species, growing in both open- and closed-canopy stands, colonizing disturbed sites and occuring as small clumps or scattered trees in late succession stands of Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*), often with lodgepole pine (*Pinus contorta* var. *latifolia*). Whitebark pine is a keystone species. Upwards of 100 wildlife species use it for food and habitat. Seeds are eaten by birds, bears, and many small mammals. It plays an important role in watershed protection by stabilizing soil, delaying and prolonging snowmelt, and facilitating revegetation following disturbance.

Regeneration Whitebark pine relies entirely upon seed for reproduction. It starts producing cones around age 40 to 50, reaching full production after age 100. The interval from cone initiation to seed maturity is two years; mast crops are produced every three to five years with low or no seed output in the intervals. The Clark's nutcracker (*Nucifraga columbiana*) has evolved a mutualistic relationship with whitebark pine. These birds break cone scales with their bills to collect the large, nutritious seeds and store up to 100 seeds in a uniquely evolved pouch under their tongues. They cache single or groups of seeds in two to three centimetres of soil, often warm exposures where snow is minimal. Uneaten cached seeds are the only known germination source. Seed caching causes the frequent clustered patterns; individuals within a clump can only be distinguished by genotyping and are often related. Fire encourages whitebark pine regeneration by reducing competition, and creating openings attractive to Clark's Nutcrackers for caching seeds and favourable to tree establishment.

Evolution and Genetics Genetic variation in growth and disease resistance traits have been demonstrated through progeny testing of selected parents. Parents and progeny that have resistance to blister rust are established in orchards for seed production of resistant stock. Genetic studies show considerable diversity within populations and limited variation between populations, with individuals from within a cluster being more closely related than individuals from different clusters within the population. Some regional patterns for adaptive traits including phenology and cold hardiness have been identified.

Whitebark pine is undergoing rapid decline. Slow growth, late maturity, and persistent threats make gene conservation urgent. This species is extremely well conserved across its Alberta range in the network of Rocky Mountain protected areas, but passive in situ conservation alone cannot mitigate or reverse threats to the species. In situ gene conservation must include active restoration with genetically diverse disease resistant seedlings with moderate to high levels of white pine blister rust, and creation of suitable regeneration sites to be effective.

Appendix 2. Information resources for distribution and abundance of tree species

Information resources for distribution and abundance of tree species include:

- Alberta Vegetation Inventory;
- Alberta Biodiversity Monitoring Instutite;
- permanent sample plots;
- temporary sample plots;
- Alberta Regeneration Information System;
- Ecological Land Classification maps;
- Ecological Land Classification reports;
- Ecological Site Information System;
- satellite imagery;
- National and Provincial Parks species lists and reports;
- naturalist botanical surveys;
- Alberta Conservation and Information Management System (ACIMS) records;
- herbarium records (e.g., eFlora-BC)
- project development environmental impact assessment baseline data and reports (national and provincial);
- bioclimatic envelope and biophysical models;
- expert advice from local or regional ecologists, botanists, and foresters;
- unpublished data, e.g. theses, internal reports with maps and coordinates; and
- published scientific literature.

It is essential to keep in mind the scale at which the data were collected, and the purpose they were collected for to make appropriate inferences and to be aware of data limitations. It is impossible to record all species' locations, and it is unlikely data such as density of minor species, and often their occurrences, will be available. Inventories may combine some species within a genus, and other species with taxonomic challenges may be difficult or impossible to find accurate data on (e.g., *Salix*, *Betula*, *Populus*). This report characterizes species distribution based on available information but local knowledge and ground truthing are necessary before confirming conservation reserve location and size.