GENE CONSERVATION PLAN FOR NATIVE TREES OF ALBERTA

May 2009

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Government of Alberta
Sustainable Resource Development

Government of Alberta
Tourism, Parks and Recreation

Preface

This plan was developed jointly by the Forestry Division of Alberta Sustainable Resource Development (SRD) and the Parks Division of Alberta Tourism, Parks and Recreation(TPR). It was developed as part of a formal agreement by these two agencies to co-operate in forest genetic resource conservation and in response to a request by the Alberta Forest Genetic Resources Council (AFGRC), who had identified as an issue, the need for a provincial forest tree gene resource conservation plan.

The plan is a technical document intended to complement and align with existing policy, particularly the Standards for Tree Improvement in Alberta (STIA). It provides a framework, including concepts for tree gene conservation and an initial work plan for implementing, coordinating and maintaining a provincial network of *in situ* reserves for 28 native Alberta tree species. Partners in implementation of the plan include SRD and TPR (under their co-operative agreement) and forest companies involved in tree improvement activities covered by Controlled Parentage Programs (CPPs) and conservation requirements under STIA.

As public land management agencies with complementary land base management and stewardship responsibilities, TPR and SRD have primary responsibility under the plan for establishment of *in situ* reserves for non-commercial species and commercial species or populations not covered under tree improvement programs. Companies involved in tree improvement have the primary responsibility for establishment and maintenance of reserves for species and populations covered under CPPs.

The plan will be reviewed and updated as more is learned regarding the conservation gaps and biology of species. At present, there is limited information regarding the range and biology of some species. GAP analysis may indicate that some additional areas will be required to provide adequate protection for some of these species. At present, a further limitation occurs due to land management responsibility and ownership, as there are forested areas falling outside the jurisdiction of the present partners, which may contain important native tree genetic resources (e.g., federal parks, Indian Reserves and deeded lands).

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Executive Summary

Genes represent the potential of any organism to adapt to its environment, whether that environment is stable or rapidly changing. For Alberta, the genes of native trees are a heritage resource reflecting evolution in changing environments. Because there is no possibility of maintaining stable environments on a large scale, climate change in Alberta (Barrow and Yu 2005) in any direction will have an impact on the survival of species. Conservation of genetic variation thus is the principal means of fostering the long-term survival of species.

Twenty-eight tree species have been identified as native to Alberta. These species range from those widely distributed and abundant in many areas to those found only in a few locations and in small numbers. Currently, two of the provinces twenty-eight recognized tree species are considered endangered under the *Alberta Wildlife Act,* namely whitebark pine and limber pine. Even among the generally abundant species, some populations are small and isolated, a circumstance that may result in the development of combinations of genes that warrant conservation. Among the species that are uncommon, the survival of some in Alberta is of concern.

Detailed knowledge of patterns of genetic variation for tree populations across Alberta is minimal for a few species and non-existent for many. Any effort to conserve genetic variation, therefore, will rely on the established relationship of genes to environment. The general environmental patterns of Alberta have been classified through the identification of Natural Regions and Subregions, and that classification will be used as a surrogate for the non-existent genetic maps. Implementation of the plan involves the following steps:

- estimate the natural distribution of each species;
- choose areas where environmental differences suggest associated genetic differences;
- request, from local contacts, candidate populations to provide an adequate genetic sample;
- from the candidate populations, verify those already under protection;
- identify candidate populations in species/Natural Subregion combinations warranting additional protection;
- work to secure additional protection where needed;
- develop brief plans for management of protected populations;
- follow-up with reporting and monitoring.

This is a large task and will be phased over a 7-year period. A formal protocol will be used to establish priorities by species, the initial emphasis being on two species for which large-scale planting of genetically improved trees is in progress (lodgepole pine and white spruce) and two species that are highly vulnerable to disease, fire management and climate warming (limber pine and whitebark pine). 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.

Acknowledgements

This plan was developed by the Working Group on Native Tree Gene Conservation in Alberta, a cooperative effort between the departments of Sustainable Resource Development and Tourism, Parks and Recreation. Members of the group were Lorna Allen, Leonard Barnhardt, Narinder Dhir, Joyce Gould, Donald Lester, Todd Kemper and Ksenija Vujnovic.

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Endorsements

Alberta Forest Genetic Resources Council, 2006

Table of Contents

List of Tables

List of Figures

1.0 Introduction

Genes represent the potential of any organism to adapt to its environment, whether that environment is stable or rapidly changing. For Alberta, the genes of native trees are a heritage resource reflecting evolution in changing environments.

Much of Alberta was covered by ice during the last glacial period and thus genes reflect change since the recession of glaciers 10,000 years ago. However, some areas were not glaciated during the last glacial event and may have provided habitats in which species survived. The genes of species from these areas may thus reflect changes over a longer period of time. Because there is no possibility of maintaining stable environments on a large scale, climate change will have an impact on the survival of species. Conservation of genetic variation thus is the principal means of fostering the long-term survival of species.

Evidence from many sources, including historical records, fossils and ice cores, for example, provide overwhelming evidence that environments change, sometimes rapidly and in major ways. For native trees, the causes of environmental change can be abiotic, as in climate change, or biotic as in pest epidemics. Available genetic variation provides the raw material for adaptation to environmental change.

In addition, land use has implications for genetic resources. Land clearing for non-forest uses removes genetic resources that, in the case of populations at the margins of species' ranges, may not be represented elsewhere. Artificial regeneration of forests, especially where there are changes in species or where the new forest is the product of genetic improvement, represent changes in local genetic resources. Even where natural regeneration is desired, practices such as fire suppression or events such as wildfire, may lead to a loss of genetic variation if regeneration is suppressed as well.

The certainties of environmental change, genetic change resulting from human intervention and the relationship between genetic variation and environment combine to determine several important reasons for gene conservation in native trees. These are noted in Section 3.

1.1 Tree Gene Conservation in Canada

Canada has 416 million hectares of forested land that represents about 10% of the world's forests. The importance of tree gene conservation in relation to forestry practice has long been recognized and was discussed at a symposium organized by the Committee on Forest Tree Breeding (now Canadian Forest Genetics Association) in 1971 (Fowler and Yeatman 1973). The national program for forest tree gene conservation is developed by the Canadian Forest Service and is based at the National Forest Genetic Resources Centre in Fredericton, New Brunswick.

The main responsibility for conservation of genetic resources of trees lies, however, with the provinces as part of their land and forest management mandate. Status of forest genetic resources conservation varies considerably across Canada; a good description of the programs is given in a technical report entitled *Forest Genetic Resources Conservation and Management in Canada* (Nieman et al. 1995).

1.2 Tree Gene Conservation in Alberta

Alberta has vast natural forests, which occupy nearly 60% of the province, an area of approximately 38 million hectares (ha). Forestry and related ecosystem services contribute approximately $8.4 billion per year to the provincial economy (ASRD 2001). Approximately 82,000 ha of forests are harvested annually. Approximately 82 million trees are planted annually for forest regeneration.

The province also has a network of parks which consists of 501 designated areas with a total of 2.76 million ha. The network has areas in several classes ranging from ecological reserves, which have the highest level of protection, to provincial recreation areas which have the lowest level of protection. The array of classes is as follows:

- 15 ecological reserves
- 3 wilderness areas
- 32 wildland parks
- 1 Willmore Wilderness Park
- 75 provincial parks
- 1 heritage rangeland
- 144 natural areas
- 230 provincial recreation areas.

It is anticipated that many of these parks, although not all, will have significant populations of tree species that can contribute to the *in situ* conservation of tree genetic resources. This use fits well with the vision for Alberta's parks, as given below:

> *"Parks and protected areas are valued as natural landscapes that preserve the environmental diversity of the province and inspire society to enjoy and rediscover our connection with the natural world"*

This is articulated further in the preservation goal of "preserve, in perpetuity, a network of parks and protected areas that represent the province's natural heritage and related cultural heritage". Conservation of genetic resources fits well with this goal. In addition to these areas, five National Parks in the province cover 5.4 million ha, a large portion of which is forested.

Conservation of wild forest gene 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 Sustainable Resource Development and the latter is part of the mandate of the Parks Division of Alberta Tourism, Parks and Recreation. Endangered species are covered under both provincial and federal legislation. The *Wildlife Act* is administered provincially by Alberta Sustainable Resource Development and the *Species at Risk Act* is administered federally by Environment Canada.

The concept of Sustainable Forest Management (SFM) originates from 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 entitled "Sustainable Forests: A Canadian Commitment". The concept led to the Canada Forest Accord on Sustainable Forest Management which was signed by the Alberta Government in 1992. The goal of the 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 (Can. Council For. Min. 2003). Maintenance of biological diversity, including genetic diversity, is a key *criterion* for SFM. 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.”

The status of conservation efforts for native tree species within each ecozone is specified as a Core Indicator for the maintenance of genetic biodiversity. Alberta has undertaken a number of initiatives to meet its commitment to implement SFM. Overall guidance for policy development and forest management planning for Alberta’s public forests is provided by the Alberta Forest Legacy document (Anon. undated), developed in 1998 through extensive discussions with the public and stakeholders on the desired state and the role of future forests.

The setting aside of heritage areas and ecological management of the forest land based on the principle of adaptive management are important features of the Alberta Forest Legacy. Standards for Tree Improvement in Alberta (ASRD 2005) provide specific policy and guidelines for incorporating genetic resources conservation in tree improvement deployment and forest management plans.

Conservation of forest genetic resources in Alberta was described by Dhir and Barnhardt (1995). Early programs for conservation were largely driven by heritage and scenic resources protection. Later, the issues of habitat protection for rare and endangered species and protection of genetic resources *per se* became dominant.

A systematic effort for forest tree gene conservation was started in 1975 as part of the provincial tree improvement program, but the work was mostly limited to a few commercial forestry species. Since then, the urgency and importance of forest gene conservation of wild forest have greatly increased because of an accelerating pace of forest harvesting and replacement of the natural forest with artificial regeneration, as well as landbase depletions due to industrial, agricultural, urbanization and recreational activity. Disturbances due to natural and introduced pests as well as fire may also play a part. This report discusses and details a plan for conservation of gene resources for 28 native tree species and their natural hybrids found in the six Natural Regions of Alberta.

1.3 Purposes of the Plan

With Alberta Sustainable Resource Development’s joint stewardship responsibility with the forest industry to implement SFM, including actions to maintain both biological and genetic diversity, and Alberta Tourism, Parks and Recreation’s goal to “preserve, in perpetuity, a network of parks and protected areas that represent the province’s natural heritage and related cultural heritage,” the purposes of the Forest Tree Gene Conservation Plan for Alberta are to:

- assess the adequacy of existing protection for native tree gene resources;
- identify gaps in existing protection;
- fill gaps in existing protection;

- co-ordinate how to achieve and maintain adequate protection.

These purposes are intended to meet an overall objective of maintaining adequate genetic diversity in Alberta forest tree species now and for the future.

1.4 Scope of the Plan

This plan will attempt to identify existing and needed gene conservation for native tree species of Alberta on a province-wide basis. Requests for additional protection, however, will be currently limited to provincial public lands. Other lands are under three classes of jurisdiction:

- National Parks (there is already some degree of protection);
- Other federal jurisdictions (e.g., lands allocated to First Nations, wildlife sanctuaries) where there may be opportunities to work cooperatively with First Nations and the Canadian Forest Service; and
- Private lands where it may be possible to work with non-governmental organizations or municipalities (through conservation easements, for example).

2.0 Genetic Resources Conservation — Concepts and Principles

2.1 Scientific Concepts

♦ **Populations of each native tree species differ genetically from place to place.**

The relationship between the distribution of plants and geography has been recognized for 25 centuries (Woodward 1987). Within the last 150 years, the role of genes and genetic processes in plant distribution has been clearly demonstrated. Moreover, the role of genes has been extended to identifying genetic differences among populations of the same species in different locations.

Knowledge of genetics is fundamental to conservation of gene resources. Genes are the fundamental unit of inheritance. An organism such as a tree may contain as many as 100,000 functional genes. Each gene may have two or more alternate forms (alleles) differing in their DNA sequence and affecting the function of the gene product and the trait it may express. The genes may be expressed at different developmental or life stages of a tree and their expression is determined by or modified by the environment. An individual's genetic composition (genotype), in conjunction with its environment, determines its observable characteristics (phenotype).

Some traits are strongly inherited and their expression is affected by the environment only to a small or minor extent. The inheritance of these traits (referred to as qualitative traits) may be determined by one or a few major genes (e.g., flower colour) and they show discontinuous variation or phenotypic expression. Other traits such as growth, phenology, cold hardiness, etc., are generally determined by many genes and their expression is affected by the environment to a moderate or substantial extent. Such traits are referred to as quantitative traits and they show a continuous pattern of variation.

The sum total of all variation among the genes and their alleles is known as genetic variation and influences the expression of a variety of traits that make up the organism. The traits may be adaptive (survival, growth, frost hardiness) or non-adaptive (some morphological traits). Genetic variation can be observed at various levels; i.e., among species, populations within a species and individuals within a species. This results in differing phenotypic expression of a variety of traits among individuals, populations and the species as a whole.

The genetic variation among individual trees in a population and among populations within a species is known as genetic diversity. That variation is the raw material upon which the forces of evolution act to bring about genetic change in successive generations of the organism. Genetic diversity is essential for maintaining ecological fitness of the populations in response to changing environmental and biotic stresses.

The study of adaptive properties of populations in relation to their environment is called genecology. Adaptive responses of populations are typically genetic and lead to population differentiation in relation to ecological habitat and climates found in the species natural geographic range. Population differentiation may show continuous (clinal) or discontinuous (ecotypic) variation pattern across climates or habitats along a species distribution. The variation among populations of trees in Alberta for adaptive traits is considered to be mostly continuous or clinal.

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 common environment (provenance testing). With environmental variation minimized, the main differences in performance are attributed to genetic differences. Such studies sometimes included assessment of taxonomic traits as well and have supported (or sometimes contradicted) classical taxonomic treatments of within-species variation.

♦ **Genetic differences among populations usually are associated with differences in environments.**

In addition to demonstrating genetic variation, provenance test results often have been expanded to the study of which elements of geography are most important in explaining genetic differences. The early studies involved measures of association (correlation, regression), for example, between tree height and latitude or elevation of seed origin. These studies provided guidance for how far seed could be moved for reforestation without serious consequences in growth or survival. In recent years, such studies have emphasized associations between genetic differences and elements of environment, principally climate.

Associations between tree height and length of the growing season at the seed origin, or survival and amount of rainfall during the growing season at the seed origin are typical for nearly all species. Statistical techniques incorporating several climate variables have further demonstrated the association of genetic differences with climate. Most recently, these approaches have been extended to predict the response of tree species to climate change and to identify the location of populations of trees that would have a genetic structure to match a changed climate.

♦ **Gene conservation requires a sample of populations in different environments**

For gene conservation of native trees in Alberta, the association of genetic differences with environment means that genetic resources must be sampled in several environments. The sampling of genetic variation in a wide range of environments should maintain adequate diversity for adaptation, perhaps to the point of speciation. Environmental classification by Natural Subregions (see Section 5.0) provides an initial level of environmental differences within which to sample.

♦ **The focus of this plan is conservation of genes in native tree species using principles of quantitative genetics and ecology**

At a species level, conservation biology might be defined to include conservation of all biological elements of a species and the interaction of that species with its associates, even humans. For purposes of this plan, the focus is exclusively on trees, although it is recognized that trees are always key elements in ecosystems that include many other species. Even then, a range of values is embedded in the tree component of ecosystems. Timber yield potential, environmental services (e.g., carbon sequestration, soil stabilization, nutrient cycling), aesthetic and ethical considerations and evolutionary potential are all important.

Quantitative genetics and statistical probability provide guidelines for the maintenance of genetic variation through the number of individuals maintained in an interbreeding population. It is assumed that recommended population sizes for trees will be adequate to maintain most associated plants.

Maintenance of genetic variation within a population is a function of the balance between losses and gains of alleles. Alleles may be lost as natural selection favors some at the expense of others and, the random sampling of genetic variation in each sexual cycle fails to include all variation. The latter effect is called genetic drift and becomes increasing important as the number of individuals in a population becomes small. By contrast, genetic variation in populations can be increased by mutation and, possibly, by migration of genes from other populations.

Calculations of the minimum number of individuals required to avoid loss of genetic variation typically assume that all individuals contribute equally to reproductive output through random mating. This is never the case for forest trees, so additional individuals are required. Aitken (2000) summarizes literature on the topic and concludes that "...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." As a working number, 5000 individuals of reproductive age per population has been chosen as the minimum number of individuals to seek for gene conservation in this plan. Yanchuk (2001) similarly suggests 5000 individuals and calculates that a population of that size would probably maintain at least five copies of recessive alleles present at a frequency of more than 0.08.

♦ **Species and populations differ in the need for gene conservation**

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 how and where a species is naturally distributed. Species with large continuous distributions are far less vulnerable than those with fragmented distributions of relatively small populations.

For species of commercial importance, even wide distribution will not prevent fragmentation of wild populations where artificial reforestation with genetically improved planting stock is commonly used. In addition, the impact of pest epidemics, fire and land use can endanger gene resources in species of either common or uncommon distribution.

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 the conservation effort as efficient as possible.

2.2 Approaches to Conservation

♦ **There are two basic methods of gene conservation — *in situ* and *ex situ***

In situ gene conservation consists of maintaining wild tree populations in their natural habitats, along with their common associated plants, and maintaining these under the influence of natural evolutionary processes. *In situ* conservation can be carried out in designated areas in conjunction with parks and other protected areas including tree gene conservation areas.

Ex situ conservation consists of conserving representative samples of wild tree genes away from their original location and, usually, outside their natural habitat. The most common technique of *ex situ* gene conservation is collection of representative seed samples from wild populations and storing these in seed banks. Other techniques consist of collection and storage of pollen, collection of scions and cuttings and establishing these in arboreta or plantations, and tissue culture and *in vitro* storage. Trees established in research trials and plantations, seed orchards, provenance and progeny trials and botanical gardens are also forms of *ex situ* gene conservation.

Ex situ conservation may be required for rare or endangered species or populations or where the native habitat of a species or population may be threatened. It is especially important for conservation of valuable genetic stock in tree improvement and plant breeding programs.

In situ and ex situ conservation methods serve different gene conservation needs and are complimentary to each other. As an additional safeguard, 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. One example is populations whose survival is threatened by pathogens (e.g., limber pine and whitebark pine). Another example is where natural regeneration is unlikely to return a similar sample to the site (e.g., the progression of species in forest succession). Although this plan emphasizes *in situ* conservation, it is expected that some *ex situ* measures, particularly seed collection and storage, will be required.

- **There are some 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 the density and distribution of the target species within the area. Expected periodic mortality rates of the target species also need to be taken into account.

The optimal reserve design consists of a core area with a stable habitat, surrounded by a buffer zone and, where possible, a transition zone (Hawkes et al. 1997). The core area should contain the desired population numbers of the target species (usually 5,000 or more) and is designed for gene conservation and monitoring activities (these may include areas and activities as specified in STIA 20.3 through 20.6 where tree gene conservation is the primary management objective).

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. It also provides a modest isolation to the target population in the core reserve from pollen contamination from planted non-natural forest that may be located nearby. The buffer area also allows possible extensions of the core area should that become necessary at some future point. In principle, the use of buffer areas should be limited to conservation-related activities such as research and education, and those consistent with gene conservation management objectives.

Where feasible, the buffer zone should be surrounded by a transition zone where land use may include activities such as logging but reforestation may be carried out with local seed sources of the target species only or with some other suitable species. In some areas, however, genetic resources can be maintained with reforestation using reproductive material collected from, and returned to, the conservation area. It is desirable to have an *in situ* reserve as a compact area (without fragmentation by roads, pipelines, seismic lines, etc.) and with minimal edge effect. A circular or near circular shape is the most efficient.

These general principles will be applied where feasible based on fulfilling the mandates of cooperating agencies, species needs and land use considerations. The Standards for Tree Improvement (STIA) apply to participants in tree improvement programs working with species approved under Controlled Parentage Program plans (see Section 6.3 and Appendix 5).

- **Duration and sustainability**

The need for gene conservation presumably will exist in perpetuity although a variety of changes could increase or lessen that need for particular species. Climate changes that alter the distribution of species, fire or accelerated human disturbance could raise the need. Increased use of natural regeneration or expansion of species ranges could reduce conservation needs. For the present, the choice of methods and areas will include consideration of sustainability over a planning framework of about 200 years. For *in situ* areas, sustainability will mainly involve management that returns local genetic variation to the area. This may be accomplished either through natural regeneration or by planting trees grown from seed collected in the protected area.

3.0 Objectives for Gene Conservation

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 representative populations of trees *in situ*. If populations of adequate size are maintained, natural selection can proceed and loss of genetic variation resulting from gene sampling in small populations will be avoided. For many protected areas, genetic variation supplemented by migration will occur only if alleles migrate from artificially regenerated forests, an outcome that reserve design will attempt to prevent.

For rare and endangered populations, this objective will be much more difficult to meet. Populations of rare and endangered species are few in number and usually small in size. Maintenance of genetic diversity may require the supplementation of *in situ* protection with *ex situ* protection where response to evolutionary processes is difficult or impossible to achieve.

2. Maintain populations of known exceptional genetic value

Although genetic variation in trees is most generally characterized by gradual change over distance, populations with exceptional combinations of genes are occasionally identified. Resistance to insects and diseases is an important example as are areas of natural hybrids. These populations need to be protected.

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

Standards for seed collection for artificial regeneration of forests are designed to maintain the level and quality of genetic variation present in harvested populations. Seed collection, storage and nursery practice, however, are likely to result in some changes to the array of alleles returned in the regenerated forest. More certain change is explicit where regeneration is with genetically improved trees. The maintenance of representative populations of trees in wild forests will provide genetic reference points for genetic diversity and genetic change.

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

In Section 6.0, it is noted there is a lack of information about the geographic patterns of genetic variation for native trees of Alberta. The same applies to relationships between genetic variation and climate, genetic structure within populations and other features of genetic variation. There is significant genetic information for only a few tree species in Alberta. Maintenance of wild populations, therefore, is essential to retain the ability to address such questions.

The results of scientific study of wild populations of trees are important to the forestry community and to the public. Knowledge of genetic variation is required for informed forest management. Genetic diversity is both a public and industry concern. Both groups value wild populations for their many attributes.

Wild populations provide the only genetic raw material for the initial stages of tree improvement. As tree improvement programs advance, it is common for tree breeders to return to wild forests to expand the range of genetic variation in breeding populations or to add genetic variation for traits not originally emphasized in breeding.

4.0 Species Covered, Their Characteristics and Conservation Needs

A list of native tree species was prepared (Table 1). For this document, a tree is defined as a perennial woody plant at least 5 m in height at maturity, whose stem (trunk or bole) supports a crown.

It is important this plan provides information to a general audience about principal features of Alberta tree species. This information includes species characteristics, natural distribution, commonly associated tree species, mode of natural reproduction, patterns of genetic variation and the main features to be addressed in assessing whether the genetic resources of each species are adequately protected. The first four features are summarized in Appendix 1. Natural distribution, general ecology, regeneration and patterns of genetic variation are features of life history considered to be central to gene conservation.

The description of each species is intended to stand alone and, therefore, there will be common elements for closely related species. Natural hybrids are noted in the descriptions of both parental species.

The information in Appendix 1 comes from several sources including guides to tree identification, maps of natural ranges, summaries of life history and ecological context, and many reports in scientific journals on different aspects of genetic variation. Published information has been supplemented with authors' personal experiences in Alberta for topics such as natural distribution, ecological context and genetic variation.

Although there are many reports on genetic variation for some species, only a few include material from Alberta and, for several non-commercial tree species, no genetic research has been done. Summaries that include current results of genetic research for specific tree species are not common. However, the general patterns of genetic variation among and within tree populations are similar for most species and can serve to guide recommendations on gene conservation. We have chosen, therefore, to avoid listing the large number of individual research reports on genetic variation in tree species that are represented in Alberta.

Attributes of each species are discussed under the following four topics. These topics and the intent of their contents are as follows:

- **Species Characteristics** — brief notes on taxonomic features such as tree size and form, bark color and structure, traits of leaves and reproductive structures, similar species in Alberta and unusual characteristics to provide a quick guide to species recognition.
- **General Ecology** — a summary of natural range, distribution in Alberta, commonly associated tree species and noteworthy features of habitat to establish an environmental context.

Table 1. Tree species native to Alberta.

Common name	**Scientific name**
balsam fir	*Abies balsamea* (L.) Mill.
Rocky Mountain alpine fir	*Abies bifolia* A. Murray
Manitoba maple	*Acer negundo* L.
Alaska birch	*Betula neoalaskana* Sargent
water birch	*Betula occidentalis* Hooker
white birch	*Betula papyrifera* Marsh.
Rocky Mountain juniper	*Juniperus scopulorum* Sargent
tamarack	*Larix laricina* (Du Roi) K. Koch
subalpine larch	*Larix lyallii* Parlatore
western larch	*Larix occidentalis* Nutt.
Engelmann spruce	*Picea engelmannii* Parry
white spruce	*Picea glauca* (Moench) Voss
black spruce	*Picea mariana* (Mill.) B.S.P
whitebark pine	*Pinus albicaulis* Engelmann
jack pine	*Pinus banksiana* Lamb.
lodgepole pine	*Pinus contorta* var. *latifolia* Engelm.
limber pine	*Pinus flexilis* James
western white pine	*Pinus monticola* Douglas ex D. Don
narrowleaf cottonwood	*Populus angustifolia* James
balsam poplar	*Populus balsamifera* L.
western/plains cottonwood	*Populus deltoides* ssp. *monilifera* (Aiton) Eckenwalder
aspen	*Populus tremuloides* Michx.
interior Douglas-fir	*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco
peachleaf willow	*Salix amygdaloides* Andersson
Scouler's willow	*Salix scouleriana* Barratt ex Hook.
western yew	*Taxus brevifolia* Nuttall
western redcedar	*Thuja plicata* Donn ex D. Don
western hemlock	*Tsuga heterophylla* (Rafinesque) Sargent

- ♦ **Regeneration** — a summary of reproductive methods (seed or vegetative), sexual maturity, flowering, fertilization and cone crop development, crop periodicity and seed dispersal; suitable seed bed conditions, germination, shade tolerance and early growth.
- ♦ **Evolution and Genetics** — the number of Alberta species in the genus, relationships of each species to closely related species including frequency and expected distribution of natural hybrids in Alberta, a summary of evidence for genetic variation among and within populations (where available) to suggest how gene resources might be sampled for conservation. A list of tree taxa naturally occurring in Alberta is provided in Appendix 2. For certain genera, a table of taxonomic classification below the family level (Appendix 3) provides additional information on genetic relationships.

Recommendations for gene conservation include the following factors which are expected to guide assessment of the current status of gene conservation and potential future needs in Alberta.

- rarity (See Appendix 2 for rankings by species and Appendix 4 for definitions of rankings);
- mode(s) of reproduction and ease of natural regeneration;
- patterns of genetic variation;
- requirement for populations which are representative of each Natural Subregion;
- existence of populations at the extreme edges of a species distribution;
- threats that may endanger a species; e.g., disease, fire (or absence of fire), etc.;
- populations of known exceptional traits;
- wild genetic resources in areas where genetic improvement will change the genetic landscape.

Table 2 is a compilation of expected emphasis for gene conservation by species, arrayed in alphabetical order by genus. The intent is to provide a quick summary in which related species can be easily compared. Table 3 (see Section 5.0) shows the expected combinations of species and Natural Subregions.

Table 2. Summary of proposed emphasis on gene conservation for each species.

Species	Emphasis on Gene Conservation
balsam fir	Balsam fir is common in two Natural Subregions and uncommon in five. Gene conservation will emphasize maintenance of representative populations in Natural Subregions where the species is common. Special attention will be paid to the sampling of disjunct populations in the southwestern portion of the range, the area of potential hybridization with Rocky Mountain alpine fir and in the boreal forest to parkland ecotone.
Rocky Mountain alpine fir	For this species, the Subalpine Natural Subregion represents the core distribution where the species is common. Gene conservation will emphasize maintenance of representative populations in that subregion and should include a sample of populations in five subregions where the species is uncommon. Of special interest are disjunct populations at upper elevations of the Porcupine Hills. Some hybrid populations should be protected in the region of overlap with balsam fir.
Manitoba maple	Manitoba maple is present in four subregions and uncommon in each. To the extent that natural populations of this species can be identified, representative samples within its natural range in Alberta should be maintained. However, this plan will not include gene conservation for Manitoba maple because of the difficulty of establishing which populations are native.
Alaska birch	Alaska birch is present in nine Natural Subregions, but uncommon in most of those. Gene conservation will emphasize maintenance of representative populations in Natural Subregions.
water birch	Water birch is present in 11 Natural Subregions but uncommon in 10 of those. A sample of representative populations should be maintained. Maintenance of disjunct populations of water birch in southeastern Alberta may warrant particular attention.
white birch	White birch is widely distributed in 15 Natural Subregions but is common only in the Lower Boreal Highlands. Core populations will be protected in the Lower Boreal Highlands and gene conservation will emphasize maintenance of representative populations in other Natural Subregions. Special attention will be paid to disjunct populations found in the Cypress Hills and Crowsnest area and the boreal-parkland ecotone. Its scattered distribution and role as a minor component in upland populations of the boreal forest lowlands may pose a conservation challenge.
Rocky Mountain juniper	Rocky Mountain juniper is an uncommon species in Alberta and is found mostly in the southwest corner of the province. Paleobotanical studies indicate the climate may have been more mesic across the range of this species than it is today, suggesting conditions may be less favourable for regeneration and growth than in the past. Because of its rarity, a sample of known populations should be maintained and further study of its distribution/status undertaken.
tamarack	Tamarack is widely distributed with representation in 13 Natural Subregions and it is common in several. Gene conservation will emphasize maintenance of representative populations in Natural Subregions. Special emphasis will be placed on populations at the southwestern limit of the species distribution as well as well-stocked, high productivity upland populations of the species.
subalpine larch	Subalpine larch is present in only two Natural Subregions and is uncommon in

Species	Emphasis on Gene Conservation
	both. Because of its restricted distribution in Alberta, gene conservation for subalpine larch will emphasize maintenance of a representative sample of populations in Natural Subregions.
western larch	Western larch is present in only two Natural Subregions and is considered to be a rare species in Alberta. The focus of gene conservation will be on maintenance of existing populations. At present, Alberta has a small tree improvement program designed primarily for seed production.
Engelmann spruce	Engelmann spruce is abundant in the Subalpine Natural Subregion. In this subregion, gene conservation will emphasize maintenance of at least two core populations. In the three other Natural Subregions, where the species occurs, conservation will emphasize protection of representative populations. Populations of natural hybrids with white spruce are abundant in the Upper Foothills Natural Subregion and at least two core populations should be protected there.
white spruce	White spruce is the most commercially important forest tree species in Alberta. Although it is widely distributed, genetic improvement for artificial regeneration in several Natural Subregions and uncommon frequency in some Natural Subregions along the southern border of the range, results in three elements of particular interest for gene conservation. The first is in populations along the southern edge of the species distribution, specifically in the Cypress Hills and, perhaps, in extensions of the range into the Parklands. Representative populations in several of the Natural Subregions need to be protected. The second element derives from the high value of white spruce for wood and fiber products. This value results in commercial harvesting and the reproductive characteristics of the species make planting the common form of forest regeneration. As a consequence, there are many programs of genetic improvement aimed at increasing plantation productivity. These programs will result in changes to the genetic landscape. Gene conservation for white spruce, therefore, will emphasize maintaining samples of wild populations as the genetic landscape changes with improved plantations. It is expected that the geographic unit for gene conservation will be the seed zone in some Natural Subregions. The third element, as noted under Engelmann spruce, is that representative hybrid populations should be protected.
black spruce	Black spruce is present in 16 Natural Subregions and is abundant in several. Maintenance of representative populations within Natural Subregions should adequately capture ecological and genetic variation. A few small populations of black spruce on disjunct sites in the vicinity of the Canmore corridor warrant review as candidates for inclusion in conservation efforts along with uncommon populations in the Parklands.
whitebark pine	Whitebark pine is found only in the Subalpine Natural Subregion and is uncommon there. Populations are declining due to white pine blister rust (*Cronartium ribicola* Fischer) and mountain pine beetle *(Dendroctinus ponderosae* Hopkins*)*. An infection rate of up to 76% by blister rust has been reported in subalpine populations in southern Alberta and British Columbia (with possibly a lower rate farther north). Habitat modification as a result of climate change may represent a long-term threat. The species has been declared endangered under the *Alberta Wildlife Act*.

Species	Emphasis on Gene Conservation
	It is assumed that sexual recombination and increased numbers of offspring will allow naturally occurring genes for blister rust resistance to be expressed. Given the ongoing threat from white pine blister rust, *in situ* protection may not be adequate for the conservation of this species in Alberta, and *ex situ* regeneration, particularly by planting rust-resistant individuals, may be a useful strategy to explore. Currently, Alberta is considering a program to identify and develop genetic resistance for white pine blister rust.
jack pine	Jack pine is found in nine Natural Subregions although it is abundant, or common, in only two. Gene conservation will emphasize exceptional populations, will review the need for maintenance of natural populations in the oil-sands area and will identify, for conservation, a sample of interspecific hybrid populations in the zone of overlap between lodgepole and jack pine.
lodgepole pine	Although lodgepole pine is present in only eight Natural Subregions, it is abundant in most of those. Three elements of conservation will receive the most emphasis. First, the prospect of large-scale planting of genetically improved stock in some parts of Alberta will prompt a review of needs to maintain wild genetic resources in those areas. It is expected the geographic unit for gene conservation will be the seed zone in some Natural Subregions. Second, isolated populations along the eastern and northern margins of the species range may warrant consideration. Proposed conservation efforts for the population at Cypress Hills can help with conservation in that area. Populations in the Crowsnest Pass area may warrant special consideration in view of evidence for higher levels of genetic diversity there. Third, the desirability of maintaining a sample of interspecific hybrid populations in the zone of overlap between lodgepole and jack pine should be assessed.
limber pine	Limber pine is present in only one Natural Subregion and is uncommon there. White pine blister rust (*Cronartium ribicola* Fischer) and mountain pine beetle represent a serious threat to this species in Alberta. The species has been declared endangered under the *Alberta Wildlife Act*. Given the ongoing threat from white pine blister rust, *in situ* protection and encouragement of regeneration may not be adequate for the conservation of this species in Alberta. *Ex situ* protection, including archiving of seed and selection and cloning of trees where they can be protected from blister rust, will be considered.
western white pine	Western white pine is rare with a sporadic distribution limited to a few sites in the Crowsnest Pass and Rocky Mountains to the south. The species is known to be very susceptible to white pine blister rust, an exotic disease that has already negatively impacted the other two species of five-needle pines in Alberta. *In situ* gene conservation for this species in Alberta is not being considered at this time.
narrowleaf cottonwood	This species is found in three Natural Subregions but is common in only one. A number of threats and obstacles have been implicated in the decline of populations of riparian poplars in recent decades, particularly changes to river flow caused by damming, channelization and water diversion, but also including agricultural and residential development, livestock grazing, invasion by exotic species and gravel mining. The increased frequency of drought may also influence the future of riparian poplars.

Species	Emphasis on Gene Conservation
	Conservation efforts should be made to maintain representative populations of narrowleaf cottonwood although it is not currently clear if this can be done *in situ* or whether *ex situ* methods will be required. Similarly, maintenance of representative hybrid populations, which include hybrids between narrowleaf cottonwood, western/plains cottonwood and balsam poplar, will be required.
balsam poplar	Balsam poplar is widely distributed in Alberta but uncommon in more than one-half of the Natural Subregions where it occurs. The main emphasis for conservation will be on maintenance of unusual populations. These will include populations that include natural hybrids between balsam poplar, western/plains cottonwood and narrowleaf cottonwood. If tree improvement with balsam poplar, and especially with interspecific hybrids that combine balsam poplar with non-native poplar species, expands well beyond its current level, conservation of native balsam poplar gene resources may be important for some areas.
western/plains cottonwood	Western/plains cottonwood is found only in two Natural Subregions and is uncommon in both. A number of threats and obstacles have been implicated in the decline of populations of riparian poplars in recent decades, particularly changes to river flow caused by damming, channelization and water diversion, but also including agricultural and residential development, livestock grazing, invasion by exotic species and gravel mining. The increased frequency of drought may also influence the future of riparian poplars. Conservation efforts should be made to maintain representative populations of western/plains cottonwood although it is not currently clear if this can be done *in situ* or whether *ex situ* methods will be required. Similarly, maintenance of representative hybrid populations, which include hybrids between western/plains cottonwood, narrowleaf cottonwood and balsam poplar, will be required. Gene conservation will emphasize maintenance of a sample of existing populations.
aspen	Aspen is the most widely distributed native tree species in Alberta, occurring in 19 of the 21 Natural Subregions. With the prevalence of natural regeneration from root sprouts, there would seem to be little need for gene conservation in aspen at present although a few populations may be exceptional enough, by virtue of location or specific traits, to warrant consideration. A substantial loss of aspen stands could prompt a reconsideration of the need for conservation. Similarly, any large-scale development of interspecific hybrids for reforestation should be accompanied by assessment of the need for gene conservation.
interior Douglas-fir	Interior Douglas-fir occurs in four Natural Subregions, although it is uncommon in three of those. Gene conservation will emphasize maintenance of representative populations in the Montane Subregion and of unusual populations and individuals in other subregions where the species is found. Genetic testing has indicated unique populations in mountain corridors north of the continuous foothills range.
peachleaf willow	Peachleaf willow is at the northern edge of its range in Alberta and is uncommon in the two Natural Subregions where it occurs. Gene conservation will emphasize maintenance of a sample of existing populations.
Scouler's willow	Scouler's willow occurs in five Natural Subregions, although it is uncommon in each. Gene conservation will emphasize maintenance of representative

Species	Emphasis on Gene Conservation
	populations in Natural Subregions where the species occurs.
western yew	At the eastern limit of its range in Alberta, this species is recorded from only one location in the province. The only known population in Alberta should be maintained. This plan will not include gene conservation for western yew, however, as the reported population is in a federal park.
western redcedar	Western redcedar is rare in Alberta occurring in only two Natural Subregions at the eastern limit of its range. Given its rarity, a representative sample of populations of this species should be conserved and monitored.
western hemlock	Being at the eastern edge of its range in eastern British Columbia, it is extremely rare in Alberta and only occurs in the Montane Natural Subregion. At least one of its occurrences may be the result of cultivation. All known populations of the western hemlock in Alberta should be maintained. This *Gene Conservation Plan for Native Trees of Alberta* will not include gene conservation for western hemlock, however, as the reported populations are in a federal park.

5.0 Geographic/Environmental Units for Planning and Assessment

5.1 Genetic Variation and Environmental Classification

Adaptive genetic variation within plant species is known to be associated with differences in abiotic and biotic environments (Section 3.0). This genetic variation often can be related to geography, climate, disturbance patterns and ecological roles. It is possible, therefore, to use ecological landscape units as a stratification tool for partitioning these environments to assist in the planning and assessment of plant gene conservation efforts.

For Alberta, there is a hierarchy of environmental classification (Figure 1) with six Natural Regions at the top level. At the next level, there are 21 subdivisions of Natural Regions of Alberta (Natural Regions and Subregions of Alberta 2005). These Natural Subregions provide the first level of ecological classification, which is useful for planning and assessment of tree gene conservation efforts. Natural Subregions are ecological units reflecting regional differences in vegetation, soils, landscape features, parent materials, land-use and climate.

Although genetic variation within species is often clinal, the strength of subregions, as discrete units, is their capture of relatively homogenous areas of species presence and function both in space and time. An example of this is the Subarctic Subregion, which encompasses several non-contiguous areas occurring at higher elevations in northern Alberta hill systems. In this subregion, the number of tree species and their development are severely limited by short cool summers, long cold winters and extensive areas of permafrost. The Subarctic Subregion effectively defines environments with summer climates too cool for establishment of deciduous tree species. In addition, pine populations show less indication of hybridization between lodgepole and jack pine than is the more common condition, in milder environments, at lower elevations of this Subregion.

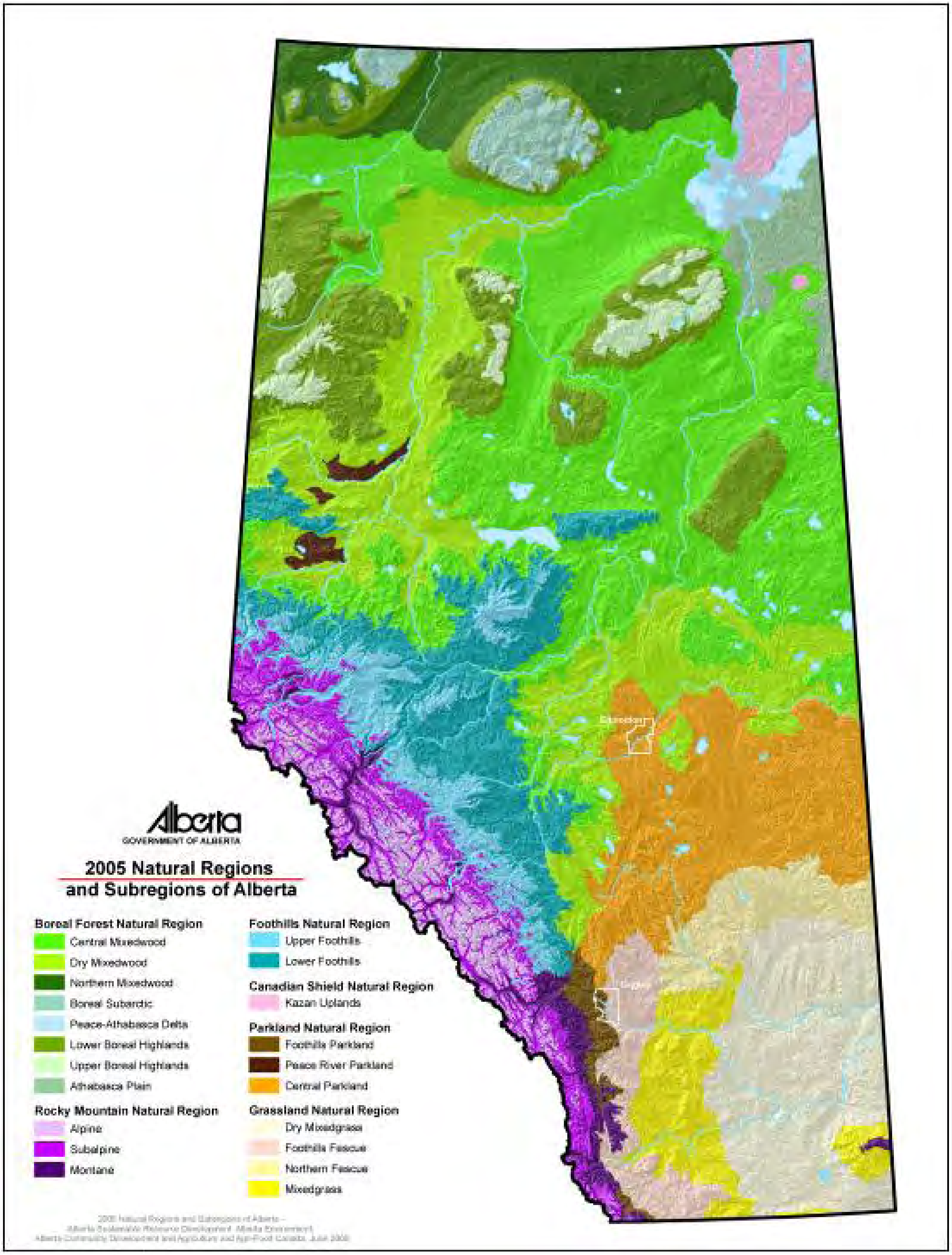

Figure 1. Map of Natural Subregions of Alberta

5.2 Need for Subdivision of Natural Subregions

The weakness of Natural Subregions for gene conservation is that they are not always defined consistently in terms of differentiating criteria, and may not always be well related to species distributions, known genetic clines or the environmental variables, which drive them. Examples where subregions are especially heterogeneous include the Montane (Strong and Leggat 1992) and Subalpine (Kojima 1980). These authors have advocated further partitioning of these Natural Subregions on the basis of ecological variation.

Another level of partitioning of ecological environments is the seed zone. These zones are more closely related to the geographic and climatic variables important in the capture of genetic variation in trees. Seed zones are nested within Natural Subregions and are based on a combination of ecological and genetic information. There are 84 defined seed zones in the province of which 74 occur within the Green Area. They are primarily devised to provide discrete zones for managing adaptive transfer of tree seed and vegetative materials in operational reforestation. As such, they provide a finer scale and more focused tool for planning and assessment of tree gene conservation.

6.0 Analysis Protocol

6.1 Guides to Sampling of Genetic Variation

The challenge of developing an appropriate sample of genetic variation for conservation would be relatively simple if a map of genetic variation was available for each species. The necessary information for such a map, however, is available for few, if any tree species. Therefore, sampling emphasizes environmental variation following the relationships between genetic variation and environment as discussed in Section 2.0.

The traditional approach to gene conservation of trees is first to stratify tree habitats by some form of environmental classification that is assumed to somewhat correspond to patterns of genetic variation. Examples include Hamann et al. (2004) and Lipow et al. (2003). For Alberta, this step has been described in Section 5.0.

Next, a survey is conducted to determine how well existing protected areas sample each of the environmental classes. Size, number and security of reserves are considered. Then the presence of target species and their abundance in each reserve is assessed. Next, the adequacy of protection for genetic resources of each species can be judged and recommendations for additional protection can be developed, if necessary. This process is often called gap analysis. Gap analysis proceeds in three steps:

- Where is the species distributed? (A first approximation is in Table 3);
- Within that distribution, what populations are already protected;
- What additional populations are deemed to warrant protection.

Initial attention is focused on protection of populations where the species is abundant (sometimes called "core" populations). Here the assumption is that genetic variation is relatively large because the species successfully occupies a range of sites. Next, consideration is given to populations at the periphery of the species distribution where populations may have diverged genetically in adapting to environments that differ substantially from environments where core populations are found. Populations at the end of ecological gradients are of particular interest.

The assumption about genetics of peripheral populations can be extended to populations that are physically separated (disjunct) from the main species distribution. Whether those populations have adapted to a substantially different environment or whether their environment is simply a sample of environments from within the main distribution of the species has not been closely studied. Disjunct populations, however, are often small and may have developed unusual genetic characteristics as a result of random genetic sampling in a small gene pool.

One other category that warrants attention for gene conservation is populations with known important genetic features. An example is the identification of unique populations of interior Douglas-fir in genetic tests of seed collections from mountain corridors.

6.2 Information Sources

Ideally, the information needed to implement the analysis is readily available in a consolidated form. Rarely, if ever, is this the case. For Alberta, information resources for distribution and abundance of tree species include:

- Alberta Vegetation Inventory (several versions);
- National Forest Inventory;
- Alberta Biodiversity Monitoring Program;
- Permanent sample plots;
- Temporary sample plots (many);
- Alberta Regeneration Information System;
- Ecological Land Classification Maps;
- Ecological Classification Reports;
- Ecological Site Information System;
- Landsat Images;
- Parks Species Lists;
- Published Scientific Literature.

For Alberta, any detailed description of where each species is distributed is beyond the availability of resources, in part, because information contained in the sources listed above is in different formats and in different degrees of detail. While species of major commercial importance usually are well covered, inventories may combine some species; e.g., those of *Abies* or *Picea*. Other species; e.g., *Salix*, may not appear in many inventories. Our approach, therefore, will be to determine species distribution where information is readily available and to rely on local knowledge elsewhere.

6.3 An Approach for Alberta

For some combinations of species and ecological units, no analysis is needed because the target species does not occur in the unit (Table 3). A quick screening using criteria such as known presence with low abundance, extensive tree improvement, etc., can sort many of the species/subregion or zone combinations into groups that require different degrees of analysis. Yanchuk and Lester (1996) show one potential approach. For Alberta, a decision tree has been developed as an aid to initial screening (Figures 2-4).

Adequacy of protection usually is expressed on an area basis with the assumption that a given area probably includes enough individuals of the target species. Population genetic theory, however, allows an estimate of the number of individuals required to reasonably assure the long-term survival of a population. That number, discussed in Section 2.0, is often given as about 5000. For species with limited population sizes and distribution, this number of individuals will not be achievable and the predominant criterion may be rarity of the species or uniqueness of the environment.

The link between area and number of individuals can be made from widely available estimates of numbers of trees per unit area at specific ages. Achievement of reproductive age is an important threshold as is anticipated longevity of trees in a protected area, especially for species of early seral stages. Target ages for each species will need to be established.

A complete gap analysis for Alberta is a very large task. With limited resources, the analysis will have to be phased in order of species priorities. Species on the ANHIC Tracking and Watch Lists and those with extensive programs of tree improvement will be analysed first. Table 5 outlines a tentative schedule for the complete gap analysis. Much of the effort will be in assembling information on the distribution of some species.

The approach for Alberta will be to choose how many areas for gene conservation are needed in each combination of species and ecological unit. Local contacts will then be asked to propose candidate areas. Candidate areas will include populations that are already in a protected status. For some combinations of species and ecological units, existing protection may fulfill requirements. Where existing protection is deemed inadequate (gaps), additional protection will be requested.

Participants in tree improvement projects operating under CPP plans are responsible for adequate protection of the target species within the deployment area. STIA standards outline their obligations and options for planning, establishing and managing *in situ* reserves under these programs (Appendix 5). Where the obligation for establishing reserves can be met within the existing "Protected Areas" network, proponents will be required to cooperate with SRD and TPR. In these instances, reserve design and management may differ from STIA based on broader objectives.

Where gaps in existing reserves are found for non-commercial species or commercial species that are not covered under a CPP, establishment of additional reserves will be required. Reserve areas will be negotiated with tenure holders but participation in establishment and management are optional.

Table 3. Matrix of species distribution and frequency by Natural Subregion.

NATURAL REGION	BOREAL								SHIELD	FOOTHILLS		ROCKY MOUNTAINS			PARKLAND				GRASSLAND		
NATURAL SUB REGION	**CM**	**NM**	**DM**	**PAD**	**LBH**	**UBH**	**AP**	**BSA**	**KU**	**LF**	**UF**	**M**	**SA**	**A**	**PRP**	**CP**	**FP**	**NF**	**FF**	**MG**	**DMG**
SPECIES COMMON NAME																					
balsam fir	O	U	U	U	O		U			U	U				U						
subalpine fir					U	U				U	O		C	U							U
Manitoba maple																U	U			U	U
Alaska birch	U	U	U	U	O	U	U	U	O												
water birch	U		U							U	U	U				U	U	U	U	U	O
white birch	O	O	O	O	C	U	U	U	U	O	U	U			U	O				U	
Rocky Mountain juniper												U	U								U
tamarack	C	C	O	U	C	O	U	U	U	C	O				U	U					
alpine larch													U	U							
western larch												R	R								
Engelmann spruce											O	U	A	U							
white spruce	A	A	C	A	A	A	U	O	U	A	O	C			U	U	U				
black spruce	C	A	O	O	C	A	C	A	C	C	A	U	U		U	U		U			
whitebark pine													U								
jack pine	C	O	O		U		A		O	U					U	U					
lodgepole pine					O	A		O		A	A	A	A	U							
limber pine												U									
western white pine												R									
narrow-leaf cottonwood										U									U	O	
balsam poplar	A	C	C	O	C	U	U	U	U	C	O	U	U		U	U	U	U	U		
western/plains cottonwood																				U	U
trembling aspen	A	C	A	O	A	U	U	U	U	A	O	C			A	A	A	U	U	U	U
Douglas-fir												O	U				U		U		
peach-leaved willow																				U	U
Scouler's willow	U		U	U						U		U									
western yew												R									
western redcedar												R	R								
western hemlock												R									

A: abundant - species is a major component of stands throughout the subregion
C: common - species is common, either with a patchy distribution or as a minor but significant component of stands throughout the subregion
O: occasional - species occurs in occasional localized patches or as a minor component in stands throughout the subregion or as a significant species in a portion of the subzone
U: uncommon - species has a minor presence within a subregion either as occasional individuals or isolated small populations
R: rare - species are listed as being tracked by ANHIC due to their limited numbers and distribution

NOTE: species are not listed for a subregion when they have a limited presence in the ecotone with a zone where the species is more common

Table 4. Natural Subregions of Alberta.

CM	Central Mixedwood
NM	Northern Mixedwood
DM	Dry Mixedwood
PAD	Peace - Athabasca Delta
LBH	Lower Boreal Highlands
UBH	Upper Boreal Highlands
BSA	Subarctic
AP	Athabasca Plain
KU	Kazan Uplands
LF	Lower Foothills
UF	Upper Foothills
M	Montane
SA	Subalpine
A	Alpine
PRP	Peace River Parkland
CP	Central Parkland
FP	Foothills Parkland
NF	Northern Fescue
FF	Foothills Fescue
MG	Mixedgrass
DMG	Dry Mixedgrass

See Figure 1 for map of Natural Subregions.

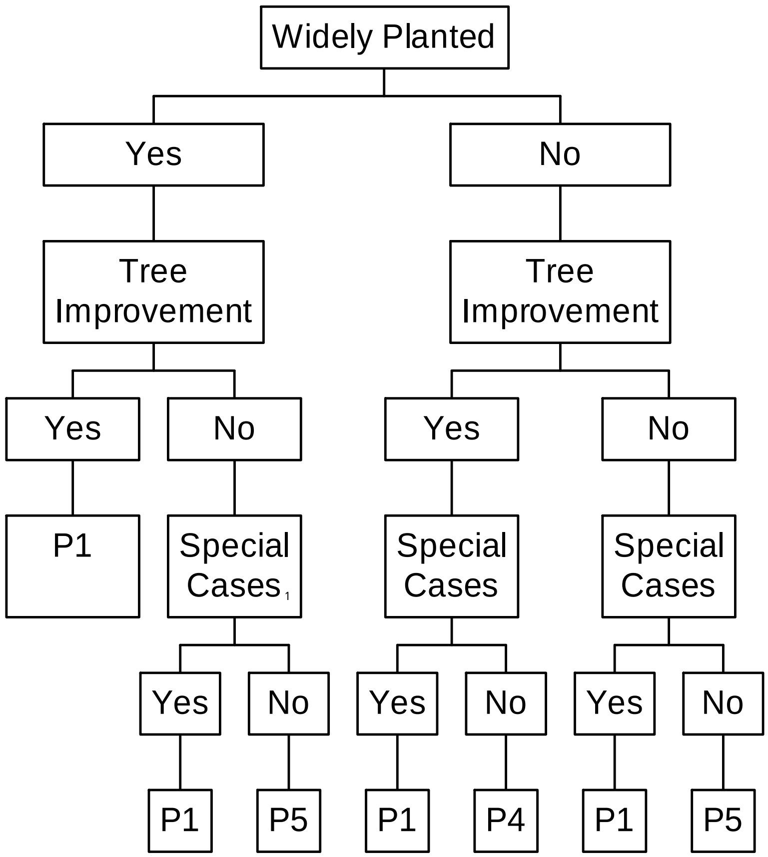

Figure 2. Decision tree for establishing gene conservation priorities in Natural Subregions where a species is abundant or common. (P1 = highest priority).

[1] *Special cases include outliers, areas with known unusual genes, ends of environmental gradients and areas with disturbance threats.*

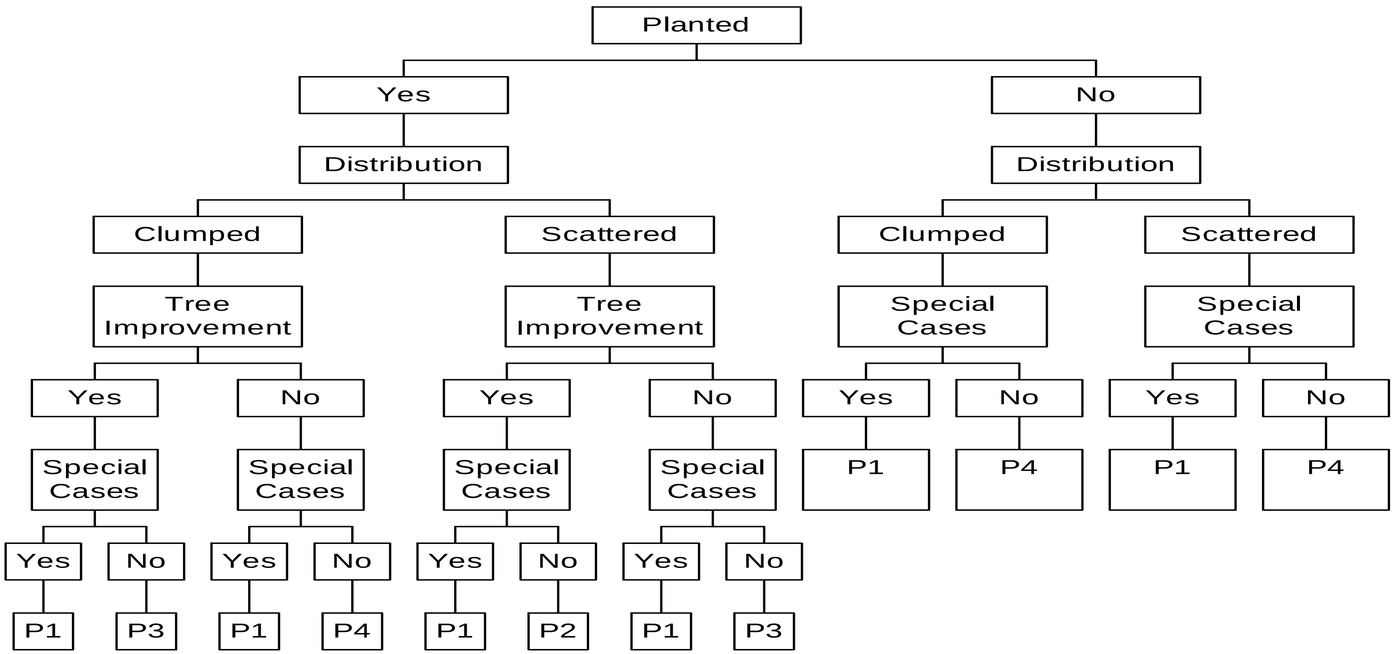

Figure 3. Decision tree for establishing gene conservation priorities in Natural Subregions where a species is occasional or uncommon. (P1 = highest priority)

[1] *Special cases include outliers, areas with known unusual genes, ends of environmental gradients and areas with disturbance threats.*

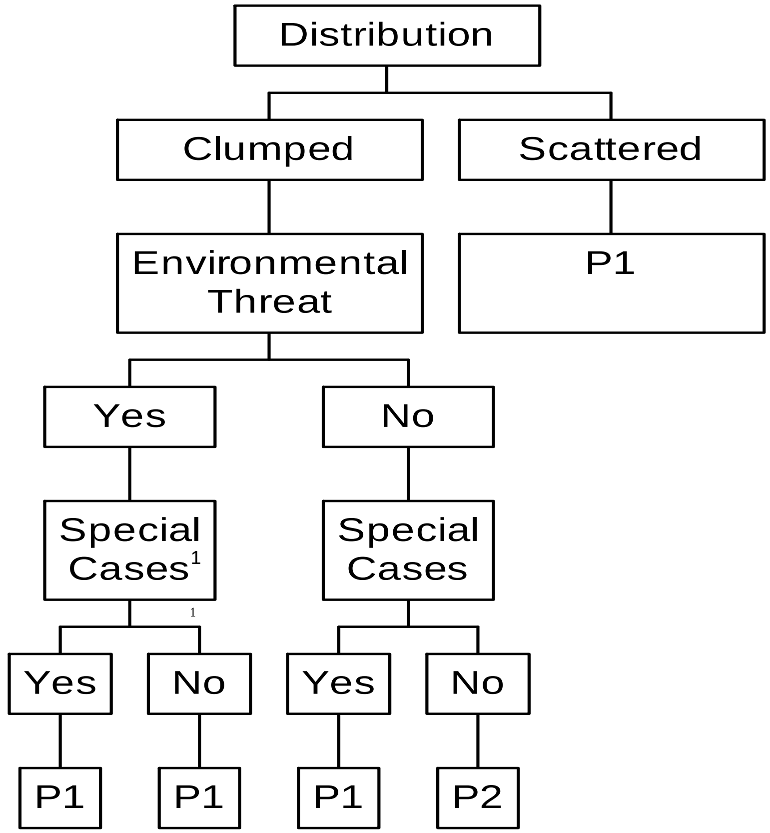

Figure 4. Decision tree for establishing gene conservation priorities in Natural Subregions where a species is rare. (P1 = highest priority)

[1]*Special cases include outliers, areas with known unusual genes, ends of environmental gradients and areas with disturbance threats.*

Table 5. Matrix of species and timeline for gap analysis.

	Year						
Species	2009	2010	2011	2012	2013	2014	2014
Lodgepole pine							
White spruce							
Western larch							
Narrow-leaf cottonwood							
Limber Pine							
Whitebark pine							
Interior Douglas-fir							
Black spruce							
Jack pine							
Peach-leaf willow							
Plains cottonwood							
Rocky Mountain juniper							
Subalpine larch							
Western redcedar							
Scouler's willow							
Alaska birch							
Tamarack							
Water birch							
Balsam fir							
Engelmann spruce							
Rocky Mountain alpine fir							
Aspen							
Balsam poplar							
Paper Birch							
Manitoba maple	no gap analysis planned						
Western white pine	no gap analysis planned						
Western hemlock	no gap analysis planned						
Western yew	no gap analysis planned						

The plan will extend some consideration beyond the borders of Alberta to recognize protected genetic resources of potential value to the province. That exercise, however, will be limited to the adjoining areas of northeastern British Columbia where there is a cooperative tree improvement program between Alberta and B.C.

Although the emphasis in this plan will be on *in situ* conservation, *ex situ* approaches may be implemented as a supplement to protected populations and where *in situ* reservations may not be feasible. A separate *ex situ* conservation plan will be developed to address the role of operational and conservation seed, linkage to the *in situ* program, special conservation needs and implementation through the following standards in *Standards for Tree Improvement in Alberta*:

17.1.1	29.2.1
17.1.2	29.3.1
17.1.3	29.4.1

7.0 Implementation Process

7.1 Getting Started

As maps of species distributions are developed, outlines of Natural Subregions or seed zones will be overlaid. For each species, Natural Subregions or seed zones will be chosen as representative for core, peripheral and disjunct populations on a province-wide basis.

Where provincial public lands are represented in each combination of species and Natural Subregion or seed zone chosen to contribute to gene conservation, a request will be sent to a local contact requesting that candidate areas be identified. The request will include the rationale for the request and some criteria for choosing areas including general location. Local contacts will be asked to coordinate efforts to locate areas with representatives of the Forest Management Branch (FMB) of Sustainable Resource Development, the Parks Division (PD) of Tourism, Parks and Recreation, and industry. Many suitable areas already may be in some form of protected status.

Upon receipt of a list of candidate areas, staff of the FMB and PD will review submissions, possibly request more information, and choose areas to be recommended for protection. Approval then will be requested from the local land manager and protective notation will be requested.

7.2 An Example

Lodgepole pine in three Natural Subregions illustrates the expected processes of implementation. In the Lower Boreal Highlands, there is substantial tree improvement activity and subdivision of the Natural Subregion into seed zones to allow sampling of genetic resources at a finer scale. Standards for gene conservation in such areas are a part of the Standards for Tree Improvement in Alberta (ASRD 2005). The Montane Subregion can be represented by a disjunct population already under protection in Cypress Hills Interprovincial Park. The Subalpine Subregion can be represented by Forest Management Unit C5 where planning for gene conservation is already in progress as a part of the Detailed Forest Management Plan.

A. Lower Boreal Highlands (Peace Region)
   1. FMB identifies seed zones.
   2. FMB contacts forest companies for local information on distribution and candidate populations for conservation.
   3. Industry and PD coordinate choice of candidates.
   4. Working Group on Gene Conservation chooses populations for conservation.
   5. Working Group requests protected status.

B. Montane (Cypress Hills Interprovincial Park)
   1. Working Group chooses general areas and candidate populations.
   2. PD to contact Park with criteria for areas and request for candidate populations.
   3. Working Group on Gene Conservation chooses populations for conservation.
   4. Working Group requests protected status.

C. Subalpine (Forest Management Unit C5)

1. FMB chooses general areas and candidate populations.
2. FMB contacts SRD area staff for local information on distribution and candidate populations for conservation with coordination with PD.
3. Working Group on Gene Conservation chooses populations for conservation.
4. Working Group requests protected status.

8.0 Monitoring and Reporting

The main purpose of a Forest Tree Gene Conservation Area (FTGCA) is to maintain genetic diversity of the designated species on-site with minimum human intervention over a long-term duration. Ideally the duration of the conservation will be 100 years or more with periodic reviews (10 – 20 years) of the status of conservation and any changes that may be needed in management of the area to fulfill its objectives.

Over this period, changes are expected to occur. The main changes of concern are disturbance (natural or anthropogenic disturbance), such as natural succession, fire, serious insect/disease occurrences and mortality of the designated species. A monitoring program is required to ensure objectives of the FTGCA are not adversely impacted. A management plan for the population is required to entail the following minimum monitoring:

1. Prepare a baseline survey of the population in year one to provide: a) estimates of the numbers of trees of the tree species present on the site and their density; b) demographics or age class distribution of the target species; and c) growth (height and diameter at 4.5 feet) data from a representative sample of trees.

2. Visit each population every 2-3 years to observe any serious biotic or abiotic damage and mortality that may impact sustainability of the target species population in the core area and the status and condition of the buffer area.

3. Survey seed crops of the population in good seed crop years to assess the potential for collection of seed for complementary *ex situ* conservation.

Every ten years, results from item #2 will be compiled in a report on the status of gene conservation on a province-wide basis for populations of native trees. Some conserved populations may include Permanent Sample Plots to provide stand dynamics (growth, yield, tree health, natural regeneration and plant succession) data. Sampling and monitoring methods for individual areas can be decided locally and will be simple and consistent with accepted forestry or ecological survey practices.

If at any point it becomes clear the area has been seriously damaged through disturbance or mortality to a point that it cannot fulfill its function and objectives, a special assessment will be carried out to determine its adequacy for continuation.

For companies working under approved Controlled Parentage Programs, refer to the Standards for Tree Improvement in Alberta 21.1.3 and 21.2.4 regarding FTGCA management and status reporting.

9.0 Glossary

Adaptation	Genetic changes, in response to natural selection, by which populations adjust to their environment.
Allele	One of two or more alternate forms of the gene, differing in DNA sequence and affecting the functioning of a single gene product (RNA and/or protein). All alleles of a series occupy the same site or locus on a pair of homologous chromosomes.
Biodiversity	The variety and variability among living organisms and ecosystems of which they are part. It has three components – ecosystem diversity, species diversity and genetic diversity.
Breeding	The science and art of changing the genetic constitution of a population of plants and animals.
Clinal or clinal variation	A continuous character gradient, usually assumed to be genetically controlled, with geography and environment. Adjacent populations merge into one another with regard to character expression with no sharp breaks.
Plant community	A group of ecologically related populations of various species that occur in a particular geographic area at a particular time.
Climax forest	The final stage in a forest succession sequence where the species composition remains relatively unchanged as long as climate and physical geography remain the same.
Ecosystem	A complex interacting system that includes all plants, animals, and their environment within a particular area.
Endangered	"A wildlife species that is facing imminent extirpation or extinction" (from the *Species at Risk Act*).
Ex situ	A method of conservation in which components of biodiversity are conserved outside of the site, away from the natural habitat.
Exotic	An introduced species or population not native to Alberta.
Fitness	The relative ability of organisms of a particular genotype to survive and produce offspring, or the contribution of one of a pair of alleles to the general vigour of an organism.
Forest tree gene conservation area	An area of forest accepted into the Alberta Forest Tree Gene Conservation Program as meeting requirements for forest gene conservation and whose primary purpose is to maintain current genetic composition and genetic diversity while allowing for natural evolutionary processes to proceed.
Gene flow	The movement of genes (i.e. alleles) within a population or between interbreeding populations as a result of outcrossing and natural selection or seed migration.
Gene pool	The totality of genes and their alleles within an interbreeding population.
Genecology	The study of the genetics of the populations of plants in relation to the ecological niches they occupy or it is the study of adaptive properties of the populations in relation to their environments.
Genetic diversity	In a group such as a population or species, the possession of a variety of genetic traits that frequently result in differing expressions in different individuals.

	The variation of genes within a species; it is the material upon which the agents of evolution act. Loss of variation may prevent adaptive change in populations of a species and reduce their ecological fitness.
Genetic variation	Differences displayed by individuals within a species which may be favoured or eliminated by natural or artificial selection. In sexual reproduction, reshuffling of genes through recombination in each generation ensures the maintenance of variation. The ultimate source of variation is mutation which produces fresh genetic material.
Genotype	The genetic composition of an individual or group that may be either expressed or unexpressed, depending upon environmental effects of a given location.
Habitat	The natural environment in which an organism or population lives. Habitat may refer to all of the organisms and their physical environment in a particular place.
Hybridization	The processes of cross-mating individuals or populations that are genetically different.
In situ	A method of gene conservation where genetic resources are conserved on site within the natural habitat.
Introgression or introgressive hybridization	The incorporation of genes of one species into the gene pool of another. If the ranges of the two species overlap and fertile hybrids are produced, they tend to backcross with the more abundant species. This process results in a population of individuals most of who resemble the more abundant parents but who possess also some characters of the other parental species.
Mutation	The process by which a gene undergoes a structural change; a modified gene resulting from mutation.
Natural range	Range of natural distribution of a taxon, excluding any portion that is the result of introduction to a region.
Natural Region	A geographic area in Alberta delineated as a part of ecological site classification and possessing a distinctive combination of physical features (climate, geology, soils, hydrology) and biological features (plant and animal species, vegetation communities). Alberta is subdivided into six Natural Regions that are: Canadian Shield Natural Region, Boreal Forest Natural Region, Rocky Mountain Natural Region, Foothills Natural Region and Parks Natural Region.
Natural selection	The process by which the genetic makeup of a population changes under natural conditions, without human interference, on the basis of its ability to become better adapted, survive or reproduce in a particular set of environmental conditions.
Natural Subregion	A subdivision of Natural Region based on biogeoclimatic factors. The six Natural Regions in Alberta are divided into 21 Natural Subregions.
Phenology	The study of timing of periodic phenomena such as flowering, growth initiation, growth cessation, etc. especially as related to seasonal changes in temperature, photoperiod, etc.
Phenotype	The sum total of the environmental and genetic (hereditary) influences on a tree; the visible characteristics of a plant.
Propagule	A live entity capable of producing a new mature individual (*e.g.*, a cutting, graft, tissue culture explant).
Population	A group of individuals of the same species that occupy a particular geographic area or region. In general, individuals within a population interbreed and

	exchange genes with each other.
Provenance	The original geographic source of seed or other propagules. Also, the test population resulting from seed collected from a particular location.
Rare	A tree species with limited natural distribution in Alberta and which is characterized by small population sizes and/or numbers.
Seed zone	A geographic area, defined on the basis of ecological characteristics and genetic information, within which seeds may be collected and freely deployed without any significant loss of adaptation and growth potential. Alberta (excluding National Parks) is divided into 84 seed zones of which 74 are in the Green Zone area. Seed Zones are subdivisions of Natural Subregions.
Tracking list	A list of species, maintained by the Alberta Natural Heritage Information Centre, that are considered to be of high priority because they are rare or of conservation concern in some other way
Threatened	"A wildlife species that is likely to become an endangered species if nothing is done to reverse the factors leading to its extirpation or extinction" (from the *Species at Risk Act*).
Taxa (singular taxon)	The general term for taxonomic groups of whatever rank.
Watch list	A list of species, maintained by the Alberta Natural Heritage Information Centre, for which data on frequency and abundance are collected but not completely analysed. If the threat to a species is found to be increasing, the name of that species is moved to a Tracking List where data are more rigorously collected and analysed.
Wild population	A population within its natural range in which the individuals are the result of natural reproduction.

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Appendix 1. Descriptions of Species on the List of Tree Species Native to Alberta

Table of Contents

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

Family: Pinaceae

	
Photo: Maryann Mochulski	Photo: 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 5 to 10 cm long and upright. Cone scales dehisce at maturity leaving the central axis attached to the branch. For similar species in Alberta, see discussion under "Evolution and genetics".

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. The species grows from sea level in the northeast to more than 3000 m 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 the northeastern corner of the province. It occurs in pure stands and in combination with white spruce (*Picea glauca* (Moench) Voss), black spruce (*P. mariana* (Mill.) B.S.P.), paper birch (*Betula papyrifera* Marsh.) and aspen (*Populus tremuloides* Michx.). It is found on soils with acid to neutral reaction and on soils that range 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, exact distribution becomes problematic due to hybridization with Rocky Mountain alpine fir (*A. bifolia* A. Murray) that occurs at mid to higher elevations of the foothills and Rocky Mountains. Distribution and identification of peripheral and disjunct stands is also problematic due to balsam fir being a shade tolerant, climax species in an area with short fire return intervals. This means a high proportion of individuals exist below the main canopy in early to mid successional stands. It is expected that some peripheral and outlier populations will occupy older stands on moister sites in the Dry Mixedwood Subregion of the Boreal Forest Natural Region.

A 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.

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. It is considered to be a species of late succession. The species responds with increased growth, however, when shade is removed.

Evolution and Genetics Balsam fir is one of about nine species of *Abies* found in North America. The number of species recognized varies by author. 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* (Hook.) Nutt.), (*A. balsamea ssp. lasiocarpa* (Hook.) Boivin) or Rocky Mountain alpine fir (*A. bifolia* Murray).

The presence of many trees with characteristics intermediate between the type specimens of balsam fir and Rocky Mountain alpine fir suggest that extensive natural hybridization has occurred where the range of the two taxa overlap. For this manuscript, the choice is to treat populations from higher elevations in western Alberta as Rocky Mountain alpine fir and to expect that hybrids will be present in areas where the distribution of balsam fir overlaps.

Studies of genetic variation among populations have shown the expected patterns of gradual change over horizontal and vertical distances. Although the more northerly and far western parts of the range have not been well sampled, transfer of seed from north to south has often resulted in spring frost injury due to early shoot elongation. Spring frost injury is an especially important problem in balsam fir and genetic variation has been identified at both the population and within-population levels.

There is no tree breeding with balsam fir in Alberta although 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.

Rocky Mountain Alpine Fir (*Abies bifolia* A. Murray)

Family: Pinaceae


Photo: Alberta Tree Improvement and Seed Centre


Photo: L. Allen


Photo: Alberta Government

Species Characteristics Rocky Mountain alpine fir is a medium-sized to large evergreen tree growing to 30 m high. It can live for 250 years. The narrow conical crown tapers to a spire-like top. In young trees the bark is smooth and ash-grey with raised resin blisters, but becomes grey-brown, furrowed and scaly as the trees age. The flat leaves are 1 to 2.5 cm long, 1 to 1.5 mm wide and have rounded or slightly notched tips. They are arranged singly and spirally around the twig although they appear two-ranked. Both surfaces bear three to six characteristic lines of white dots that are resin exudates. Male and female cones are produced on the same individual. The dark purple-grey barrel-shaped seed cones stand upright and break up while still on the tree, leaving the bare cone axis behind and persistent for several years.

Rocky Mountain alpine fir closely resembles subalpine fir, (*A. lasiocarpa* (Hook.) Nutt.); some botanists consider it to be synonymous. However, subalpine fir has a more coastal distribution, occurring at elevations of 1100 to 2300 m in a narrow strip from Yukon to California. Rocky Mountain alpine fir also is similar to balsam fir (*A. balsamea* (L.) Mill.).

General Ecology Rocky Mountain alpine fir grows in continental subalpine forests, extending from the Yukon in the north to New Mexico in the south, with extensive populations in British Columbia and Alberta. It grows at elevations of 600 to 3600 m in the Rocky Mountains, but in the Canadian provinces it is most abundant above 1500 m. It is found on a wide variety of soil types but because of its low tolerance to high temperatures and its high transpiration rates, Rocky Mountain alpine fir is restricted to cool, humid sites.

It pioneers in extreme sites but throughout most of its range, including Alberta, it occurs most frequently as a co-dominant with Engelmann spruce (*Picea engelmannii* Parry), forming a climax or long-lived seral forest. At timberline, this spruce-fir community may grow as a dense krummholz thicket 1 to 2 m high. On gentle slopes below timberline these two species often grow in strips 10 to 50 m wide and several hundred m long at right angles to the direction of prevailing winds, separated by moist subalpine meadows where snowdrifts accumulate.

By providing tree cover, this fir is important in protecting watersheds and rehabilitating mountain landscapes, and as habitat for wildlife. It is a component of the mountain ecosystems that provides recreational opportunities and aesthetic pleasure.

Regeneration Rocky Mountain alpine fir reproduces mainly by seed. Vegetative reproduction by layering, however, is particularly common on severe sites such as at timberline and on talus slopes. Open-growing trees may produce cones at 20 years of age but under closed-forest conditions, seed production is observed on older and taller trees with maximum seed production usually occurring at 150 to 200 years in dominant trees. Years of heavy seed production alternate with years of light production or crop failure. Seed ripens from mid-September to late October and is dispersed by wind from October to December. The seeds are eaten by squirrels and other mountain rodents.

Although Rocky Mountain alpine 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 under 50% shade or less. Both root and shoot growths are very slow at high elevations.

Evolution and Genetics Rocky Mountain alpine fir is one of about nine species of *Abies* found in North America. The number of species recognized varies by author. 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* (Hook.) Nutt.), (*A. balsamea* ssp. *lasiocarpa* (Hook.) Boivin) or Rocky Mountain alpine fir. *Abies bifolia* may be recognized as distinct from *A. lasiocarpa* in wood chemistry and characters of the leaf scar, periderm and bud scales.

For this manuscript, the choice is to treat populations from higher elevations in western Alberta as Rocky Mountain alpine fir. The presence of many trees with characteristics intermediate between the type specimens of Rocky Mountain alpine fir and balsam fir suggest that extensive natural hybridization has occurred where the range of the two taxa overlap. Rocky Mountain alpine fir is known to be introgressed with balsam fir in the vicinity of Lesser Slave Lake and the Athabasca River in north-central Alberta.

Genetic variation between and within populations of Rocky Mountain alpine fir has not been reported except for populations introgressed with balsam fir. Genetic variation within and between populations, however, has been identified in both of the closely related species, balsam fir and subalpine fir.

Manitoba Maple (*Acer negundo* L.)

Family: Aceraceae

Photo: Alberta Tree Improvement and Seed Centre

Photo: Alberta Tree Improvement and Seed Centre

Photo: L. Allen

Species Characteristics Manitoba maple is a lowland, deciduous tree, of small to medium size reaching about 20 m 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. These leaves are 5 to 12 cm in length, 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* spp.) 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. 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 mostly by seed. Seed production begins at 8 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. Seedlings become established readily and regeneration also occurs by sprouting from stumps and roots.

The species is somewhat tolerant of shade and, once established, can tolerate drought.

Evolution and Genetics The maples are a very diverse genus with many species. Only one species, Manitoba maple is found in Alberta. Among the many varieties of the species, two varieties have been recognized as occurring in Alberta: *A. negundo* var. *interius* (Britt.) Sargent, which is rare, and the more common form, var. *violaceum* (Kirchn.) Jaeger. Native populations are relatively rare in Alberta, as far as can be determined. However, on account of its tolerance of cold and drought, fast growth and ease of cultivation, the tree has been so widely planted for shelterbelts, along streets and in gardens throughout the province and is found virtually anywhere where there is human habitation.

Wild and naturalized forms are impossible to distinguish by eye and native populations are identified as such on the basis of their distribution. It seems likely interbreeding between planted and native populations has taken place.

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.

Alaska Birch (*Betula neoalaskana* Sargent)

Family: Betulaceae

Photo: A.J. Gould

Photo: L. Allen

Species Characteristics Alaska birch is a small to medium-size tree reaching 15 m in height and 20 cm in trunk diameter. The young bark is smooth and reddish-brown with the transverse lenticels characteristic of birch but in mature trees it is white and peels off in layers. The thin, triangular to broadly oval leaves, 4 to 7 cm long, are twice-serrate, taper at the tip and lack hairs in the vein axils. The hairless twigs are densely warty-glandular in this species. Male and female flowers are produced in catkins on the same tree, the latter on short spur shoots. A similar species is white birch (*B. papyrifera* Marshall), whose range overlaps that of Alaska birch.

General Ecology A northwestern boreal species adapted to cold climates, Alaska birch 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 part of the province, with extensions into the far northeast, but is apparently absent from the foothills and mountains and the far northwest.

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 black spruce (*Picea mariana* (Mill.) B.S.P.), white spruce (*P. glauca* (Moench) Voss), balsam fir (*Abies balsamea* (L.) Mill.) and aspen (*Populus tremuloides* Michaux). It is fast-growing as befits a seral species but it is also short-lived (not more than 140 years). Fallen birch leaves decay quickly and contributes significantly to soil improvement.

Regeneration Reproduction of Alaska birch is mainly by seed. Wind-pollination occurs in the early spring and the small winged fruits (samaras) mature in fruiting catkins, which gradually become pendent in the fall. Fruits are dispersed gradually over the course of the winter and can often be 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 conifers and other hardwoods after a few decades.

Evolution and Genetics The birches are taxonomically complex in North America with as many as ten species and many varieties and hybrids. Additional details of sub-family classification are in Appendix 3. Alaska birch is frequently treated as a variety of white birch, but according to J.J. Furlow's monograph in Flora of North America its closest affinities are with the Asian members of a circumpolar complex. For Alberta, five species are native but only three; Alaska, white and water birch (*B. occidentalis* Hooker) are classified as trees. Natural hybrids of Alaska birch with white and water birch, as well as with dwarf birch (*B. glandulosa* Michx.), have been reported.

Although genetic variation in Alaska birch has not been studied, substantial genetic variation in a variety of traits is to be expected in a species that has a wide-ranging distribution.

Water Birch (*Betula occidentalis* Hooker)

Family: Betulaceae

Photo: Lorna Allen

Photo: Lorna Allen

Species Characteristics A tall shrub or small tree growing up to 12 m high and 30 cm 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. The leaves, 2 to 5 cm long, are broadly ovate to rhombic in shape and are irregularly doubly serrate; their undersides are covered with minute resin glands.

Water birch bears male flowers in elongate catkins (6 cm long at anthesis) and fruits in shorter catkins (2 to 3 cm 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* Sargent) and white birch (*B. papyrifera* Marshall), 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 far east as northwestern Ontario, and south and east to California and Colorado. It occurs along river and stream banks on 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 The winged fruits are produced in abundance and dispersed by wind and water when the fruiting catkins shatter in autumn.

Evolution and Genetics The birches are taxonomically complex in North America with as many as ten species and many varieties and hybrids. Sub-family classification is in Appendix 3. For Alberta, five species are native but only three; water, white and Alaska birch are classified as trees. Water birch crosses with white birch to form the hybrid *B.* x *utahensis*, with intermediate characteristics. Introgression of water birch into white birch produces hybrids that have been recognized as *B. papyrifera* var. *subcordata* (Rydb.) Sargent.

Water birch is a very variable species, as may be expected given 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. E. Hultén (1968) believed that the water birches in Alaska were an extensive hybrid swarm of *B. neoalaskana* x *B. glandulosa*, but the studies did not indicate a hybrid origin for water birch in other parts of its range.

White or Paper Birch (*Betula papyrifera* Marsh.)

Family: Betulaceae

Photo: Moose Lake Provincial Park

Photo: Cold Lake Provincial Park

Species Characteristics White birch is a medium tree with white bark that peels readily in sheets. It is classed as a short-lived species that rarely lives more than 150 years. Twigs are brown, 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).

General Ecology White birch follows the northern limit of tree growth from Labrador to northwest Alaska. The southern limit is around 40° North Latitude in the East and 45° N. Latitude in the West although much of the southern distribution is spotty. Paper birch is a species of early succession, often following fire. It is shade intolerant. In addition to forming pure stands, it may be found with aspen (*Populus tremuloides* Michx.), white spruce (*Picea glauca* (Moench) Voss), black spruce (*P. mariana* (Mill.) B.S.P), lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.), jack pine (*P. banksiana* Lamb.) and their hybrids, as well as balsam fir (*Abies balsamea* (L.) Mill.). It grows best on well-drained sandy or silty soils.

In Alberta, white birch is found as a minor component of upland stands throughout northern boreal forests. It also 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, white birch is more common and forms both pure and mixed stands on upland sites. Disjunct populations are reported from as far south as the Crowsnest Pass, and one disjunct population is reported from the Cypress Hills. Peripheral populations occur along streams and rivers extending from boreal and foothills forests into the parkland.

Regeneration White birch reproduces mainly by seed. Flowering begins at about 15 years of age in forests although seed production has been achieved within the second year from seed in nursery culture, an ability that has been used in birch breeding. Large seed crops may be produced and the small, winged seeds are released throughout the year and dispersed for long distances by wind, especially on glazed snow.

The small seed of paper birch is fragile and seedlings are most easily established on partially shaded mineral soil or rotting wood. Site disturbance by mechanical means is sometimes used to improve the prospects for regeneration from seed. Birch seed may lie dormant for a year or two until moisture conditions are favorable for germination.

Regeneration by planting can be successful but competing vegetation may need to be controlled. Stump sprouts can be prolific when young, vigorous trees are cut. Sprouts are not expected to fully regenerate stands, however.

As a species of early succession, paper birch grows rapidly in the early years. Individual trees gain a dominant position quickly and substantial mortality follows unless suppressed trees are released from competition.

Evolution and Genetics The birches are taxonomically complex in North America with as many as 10 species and many varieties and hybrids (see Appendix 3 for sub-family classification of birches in Alberta). For Alberta, five species are native but only three; white, water and Alaska birch are classified as trees. Natural hybrids of white birch with water, Alaska and dwarf birch (*B. glandulosa* Michx.) have been reported. In addition, chromosome numbers range from 28 to 84 and seedlings from the same mother tree can have different numbers.

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. The results of testing show the expected greater growth potential of seeds collected in the south as compared with seeds from northern locations. This pattern, however, was somewhat inconsistent as some collections from similar latitudes in the southern part of the areas sampled demonstrated low growth rates.

There is substantial genetic variation within populations in a variety of traits including growth rate, age at which bark becomes white and resistance to insects. The quality of birch wood, the availability of genetic variation, and the ease with which flowers can be induced on very young trees have been among the reasons for interest in genetic improvement of birch in Europe. No comparable efforts have been undertaken in North America.

Rocky Mountain Juniper (*Juniperus scopulorum* Sargent)

Family: Cupressaceae

Photo: L. Allen

Photo: J.D. Johnson

Photo: D. McIntyre

Species Characteristics Rocky Mountain juniper is a small tree or, on poor sites, a shrub growing from 3 to 10 m high. Trees can live for several hundred years. It has a conic or (occasionally) a rounded crown and can be single- or multi-stemmed. The reddish- or grey-brown bark is smooth in the smaller branches but fibrous and exfoliating in strips or plates on larger ones. Its leaves, like those of most junipers, occur in two forms: needle leaves (also called whip leaves), which are subulate or awl-shaped and spread out in three or four ranks around the twigs, and scale-leaves which are appressed and scarcely overlapping. The needle leaves are 3 to 6 mm long, and light to dark green; young plants bear such leaves exclusively. The awl shaped leaves are 1 to 3 mm long, yellowish-green or whitish-green (glaucous) with 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 8 mm in diameter, and take two years to mature on the female trees. Similar species with an overlapping range is creeping juniper (*J. horizontalis* Moench) and common juniper (*J. communis* L.), which, however, are invariably prostrate or decumbent shrubs.

General Ecology Rocky Mountain juniper is a western species, generally associated with the mountains, but has in addition a scattered distribution and a wide climatic range. It extends from the glaciated valleys of northern and central British Columbia through the foothills of the Rocky Mountains to the mesas and tablelands of the southwestern US, as far south as northern Mexico. It also occurs in coastal forests on Vancouver Island.

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 1200 to 2700 m. The species may grow best in sheltered hillside ravines. Although it can occur in pure stands or as a co-dominant species in certain community types, it is usually a minor component of late seral or near-climax forest communities within most parts of its range.

Rocky Mountain juniper is associated with a wide range of forest-shrub-grassland species throughout its range. In British Columbia and Alberta at high elevations it is associated with subalpine larch (*Larix lyallii* Parl.), limber pine (*Pinus flexilis* James) and whitebark pine (*P. albicaulis* Engelm.), as well as its shrubby congeners, common juniper and creeping juniper.

Regeneration Regeneration is by seed and seed production may begin as early as ten years but is optimum between 50 and 200 years. Each fruit contains 1 to 3 seeds, which are dispersed chiefly by birds. The optimum age for seed-production is 50 to 200 years but trees may begin to reproduce as early as ten years of age under good conditions. Seed viability is fair, but seed may remain viable for several years under proper storage conditions. In collecting seed for artificial regeneration of this species, the immature fruits should be avoided. 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 may be 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. Shade tolerance decreases with age. Growth is slow.

Evolution and Genetics Rocky Mountain juniper is in the section *Sabina* of the genus *Juniperus*. It hybridizes with its eastern counterpart Eastern redcedar (*J. virginiana* L.) where the ranges of the two species overlap, with gene flow in an easterly direction, and with creeping juniper to form the hybrid (*J.* x *fassettii* Boivin). Little is known about inter- and intra-population variability in Rocky Mountain juniper, although it is expected to be considerable in a species with a scattered distribution and wide altitudinal range.

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

Family: Pinaceae


Photo: L. Allen


Photo: A.J. Gould


Photo: L. Allen

Species Characteristics Tamarack is a medium-sized tree rarely exceeding 150 years in age. The bark is rough, scaly, and reddish-brown. Leaves are 1 to 2.5 cm long, 3-angled and borne mostly in clusters on dwarf, spur shoots. Larches are unusual conifers in being deciduous. Seed and pollen cones are produced on the same tree. Seed cones are 1 to 2.5 cm long with bracts that are shorter than cone scales. Similar species in Alberta are western larch (*L. occidentalis* Nutt.) and subalpine larch (*L. lyallii* Parl.).

General Ecology Tamarack is widely distributed from Labrador to central Alaska with a large gap in distribution 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. In these habitats it can occur as open or closed stands, commonly in association with black spruce (*Picea mariana* (Mill.) B.S.P.).

It also occupies wetlands or their margins in the foothills as far south as the Red Deer River drainage. Although it is most commonly associated with the extensive wetland black spruce communities of the north, the best-developed and most extensive stands are in the nutrient rich fens and wetlands adjacent to major drainages such as the Athabasca, Peace and Hay Rivers. Peripheral populations occur along the parkland boundary with boreal and foothills forests. Several outlier stands are reported in the vicinity of the Canmore Corridor.

Tamarack is particularly vulnerable to epidemics of the larch sawfly (*Pristiphora erichsonii* [Hartig]. Defoliation can be severe and recurrent for several years resulting in high mortality and large reductions in growth. With thin bark and shallow roots, the species also is highly vulnerable to fire.

Regeneration Tamarack reproduces almost entirely by seed except along the western limit of its range. Branches covered with moss may, however, develop roots. Also, shoots developed from roots have been reported. Seed production begins at about age 15 but large quantities of seed are not produced until much later. Dispersal of the small seed is by wind. Moist mineral seedbeds with a light shade are best and flooding or drought often kills seedlings.

Tamarack is a species of early succession. It is very intolerant and will not reproduce under its own shade. Where established seedlings have adequate light and moisture, growth is very rapid.

Evolution and Genetics Of the ten species of larch, each of the three present in North America are found in Alberta. In addition to tamarack, there are western larch and subalpine larch. Phylogenetically, tamarack is considered to belong to a different group of larches than the other two North American species. There would seem to be little opportunity for tamarack to naturally hybridize with other native larches because of differences in elevational distribution and no natural hybrids have been reported. Tamarack has been artificially crossed with other larch species but seed yields have been low.

No range-wide genetic testing has been done. Genetic variation among populations has been shown within different regions. Genetic variation within populations has also been found. Differences in height growth were well expressed in provenance trials in Alberta but relationships with climatic and geographic variables were weak.

Tamarack is rarely planted for reforestation and only a small tree improvement program is in progress.

Subalpine larch (*Larix lyallii* Parlatore)

Family: Pinaceae

Photo: D. Vujnovic

Photo: J.D. Johnson

Photo: D. McIntyre

Species Characteristics Subalpine larch is a slow-growing, long-lived tree, often attaining 400 to 500 years of age. In the timberline environments in which it grows, it can reach heights of 12 to 25 m, with a trunk diameter of up to 50 cm. 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.

Leaf arrangement is distinctive. The bluish-green leaves, or needles, which are 4 to 5 cm long and less than 1 mm wide, occur in tufts of 30 to 40, on numerous distinctive short or spur shoots, or singly along the long (extension) shoots which are responsible for the growth of the tree. They are shed annually, although on young trees some remain for two seasons. Subalpine larch produces pollen and seed cones on the same tree at the ends of short shoots. Seed cones have thin, persistent scales that are subtended by awn-tipped bracts. The densely hairy twigs of subalpine larch serve to distinguish it from the similar western larch, (*L. occidentalis* Nutt.); however, the latter, despite overlapping geographic ranges, typically occurs at somewhat lower altitudes (up to 1500 m).

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 1500 to 2800 m, where it forms open, pure stands above the limit of other conifers. In Alberta, this species is restricted to the Rocky Mountains south of the Red Deer River. In its lower altitudinal ranges in Alberta it may be mixed with Rocky Mountain subalpine fir (*Abies bifolia* A. Murray), Engelmann spruce (*Picea engelmannii* Parry), and whitebark pine (*Pinus albicaulis* Engelm.).

Subalpine larch is adapted to a cold, continental climate with a short growing season. Its resistance to winter desiccation is aided by its deciduous habitat 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 are able to straighten out again when the snow melts. It is important for watershed protection, wildlife habitat (including food for blue grouse, which eat its needles) and aesthetics.

Regeneration Reproduction is almost exclusively by seed, although seedlings are rarely found. 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 appreciable seed production does not occur until the trees are at least 80 years old. Dissemination of the winged seeds is by wind. It appears that successful germination is a very rare event, taking place only under ideal conditions, which include a moist, mineral-soil substrate. Seedlings and the basal branches of young trees up to 25 years of age have leaves that last through two summers, presumably an advantage for seedling and sapling establishment.

Subalpine larch is shade-intolerant, moisture-loving and adapted to cold temperatures; it appears to achieve its best growth in high cirque basins and at the bases of talus slopes where seepage maintains a moist substrate.

Evolution and Genetics Of the ten species of larch, each of the three present in North America are found in Alberta. In addition to subalpine larch, there are western larch and tamarack. Phylogenetically, alpine larch and western larch are considered to be much more closely related than either is to tamarack. Where the distributions of subalpine larch and western larch overlap, natural hybrids have been found and the two species can be artificially crossed.

Western Larch (*Larix occidentalis* Nutt.)

Family: Pinaceae

Photo: A.J. Gould

Photo: A.J. Gould

Photo: Alberta Tree Improvement and Seed Centre

Species Characteristics Western larch is a long-lived tree (several hundred years) and the largest of all larch species. It can exceed 50 m in height. Bark is furrowed near the base of older trees. Leaves are yellowish-green, flatly 3-angled and shed annually. Seed and pollen cones are produced on the same tree. Seed cones are 2 to 5 cm long with bracts that do not greatly exceed the length of cone scales in mature cones. Similar species are tamarack (*L. laricina* (Du Roi) K. Koch) and subalpine larch (*L. lyallii* Parl.).

General Ecology Western larch is an upland and mountain species of the Rocky Mountains and east slopes of the Cascade Mountains between about 43° and 52° North Latitude. Its elevational range is from 1200 m in the north to 2100 m in the southern part of the range.

In Alberta, the species has a restricted range in the upper montane and lower subalpine forests of the Crowsnest, Waterton and Kananaskis areas. The population in Kananaskis consists of scattered, individual mature trees found in the upper canopy of lodgepole pine stands. Populations in the Crowsnest Pass and Waterton areas, although localized, have higher population densities.

Western larch has been described as a climax species where it is maintained by fire and as a seral species in association with lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.), Engelmann spruce (*Picea. engelmanni*i Parry) and Rocky Mountain alpine fir (*Abies bifolia* A. Murray). Western larch grows on deep, porous soils on cooler exposures. It is classified as shade intolerant and fire is essential for maintenance of natural western larch forests.

Regeneration Western larch reproduces by seed only. Although seed has been produced on trees younger than ten years, seed production is infrequent before age 25 and usually not abundant until ages 40 to 50 years. The small seed has a large wing and can be carried for a substantial distance by wind.

Ashes or mineral soil provide more 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 the intolerant nature of the species becomes quickly apparent in shade. In optimum conditions, western larch seedlings will match the growth rate of lodgepole pine and easily outgrow other associated tree species.

Infrequent seed crops, lack of availability of seed and unsuitable climate limit reproduction of western larch in Alberta.

Evolution and Genetics Of the ten species of larch, each of the three present in North America is found in Alberta. In addition to western larch, there are subalpine larch and tamarack. Phylogenetically, western larch and subalpine larch are considered to be much more closely related than either is to tamarack. Where the distributions of western larch and subalpine larch overlap, natural hybrids have been found and the two species can be artificially crossed.

Genetic variation associated with geography has been shown although rates of genetic change along environmental gradients are less rapid than for many forest tree species. As with most other tree species, these genetic changes reflect a balancing of growth potential with cold hardiness.

Within-population genetic variation also has been identified and forms the basis for developing genetically improved planting stock in a few programs for tree improvement. Presently, Alberta has a small program designed for seed production.

Engelmann Spruce (*Picea engelmannii* Parry)

Family: Pinaceae

Photo: A.J. Gould

Photo: Alberta Government

Photo: MaryAnn Mochulski

Species Characteristics Engelmann spruce is a large, long-lived tree, often 25 to 30 m tall or more with a narrow spire-like crown and drooping lower branches. At higher elevations it grows as a short 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, 3 to 8 cm long. Pollen and seed cones are produced on the same tree. Seed scales are papery, tapered at both ends and have a ragged outer edge. Similar species in Alberta are black spruce (*P. mariana* (Mill.) B.S.P.) and white spruce (*P. glauca* (Moench) Voss).

General Ecology Engelmann spruce is distributed 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 1200 m. Best growth is on deep, well-drained loam soils.

In Alberta, Engelmann spruce occurs as a subalpine species at high elevations along the western border of the province to about 54° North Latitude. It is commonly associated with Rocky Mountain alpine fir (*Abies bifolia* A. Murray), lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.), whitebark pine (*P. albicaulis* Engelmann) and subalpine larch (*Larix lyallii* Parl.). Hybrids between Engelmann and white spruce are common and form a relatively wide altitudinal band of introgression between 1200 m and 1800 m. The lower limit of the introgression zone is around 1450 m in the south dropping to around 1200 m in the north. Hybrids are also reported from the highest elevations in the Swan Hills.

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 as early as age 15 but maximum seed production may not be achieved for 200 to 250 years. Good seed crops may occur every 2 to 6 years.

Seedlings develop on a variety of seedbeds and can survive under low light intensities. Although early growth is slow, Engelmann spruce can continue to make good growth for 300 years and can become the largest of the high mountain species. The species, often in combination with Rocky Mountain alpine fir, is considered to be a near-climax species. On northern exposures, Engelmann spruce and Rocky Mountain alpine fir forests replace themselves after destruction, but on southern exposures, may regenerate through a stage dominated by other species of early succession.

Evolution and Genetics Four other spruce species are native to Canada; two are found in Alberta, black spruce and white spruce. Natural hybrids between Engelmann and black spruce have not been reported. Hybrids with white spruce, however, are common.

In southwestern Alberta, as the elevation of spruce forests increases, the frequency of apparent natural hybrids with Engelmann spruce increases until trees are predominantly, or entirely Engelmann spruce. Morphological traits allow some discrimination between these species and molecular techniques have been developed to more precisely estimate the degree of genetic mixing in individuals.

Considerable genetic variation is found in Engelmann spruce for growth, development, cold hardiness and terpene traits. Variation among populations is related to geography and dominated by elevational and latitudinal trends. Genetic variation among individuals within populations has been demonstrated.

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

Family: Pinaceae

Photo: L. Allen

Photo: L. Allen

Photo: 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 and usually have a strong aroma when crushed. Pollen and seed cones are produced on the same tree. Seed cones are 2.5 to 5 cm in length and reddish-brown cone scales have smooth, rounded edges. Similar species are black spruce (*P. mariana* (Mill.) B.S.P.) and Engelmann spruce (*P. engelmanni*i Parry). Infusions of green spruce twigs were traditionally used by native peoples as an effective cure for scurvy.

General Ecology White spruce is a major component of the Boreal Forest stretching across the continent from the northern limit of tree growth to near 45° North Latitude in the eastern portion of its range. In Alberta, the southern limit of the species has been placed a few miles north of Lloydminster then veering southwest with spurs along the Battle, Red Deer, and Bow Rivers, then west from Calgary. A substantial isolated forest of white spruce occurs in the Cypress Hills.

The species is common in mixtures with aspen (*Populus tremuloides* Michx.), balsam poplar (*P. balsamifera* L.), black spruce (*Picea mariana* (Mill.) B.S.P.) and lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.) and to a lesser extent with white birch (*Betula papyrifera* Marsh.) and Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) in early to mid-successional stands of boreal, foothills and montane forests. In mid- to late-succession, it may form pure stands or occur with components of black spruce and balsam fir. In the Parklands, it is often limited to north facing slopes and small populations on moister sites along the southern and eastern edge of the distribution.

White spruce occupies a wide range of soils and can behave either as a pioneer species in disturbed habitats or as a climax species following aspen. It is an important species for thermal shelter during winter and its seeds are an important source of food for many species of birds as well as red squirrels.

Regeneration White spruce reproduces naturally only by seed and dispersal is mainly by wind. Good cone production generally begins at about 30 years of age with substantial crops at 2 to 6 year intervals. In colder climates, however, seed production may be less frequent. Seedbed moisture is the most important factor in establishment from seed although dense growth of competing vegetation on the seedbed is also an important determining factor.

As a major source of wood for lumber and wood pulp, white spruce forests are generally harvested at ages ranging from 75 to more than 120 years of age. Reforestation is most commonly achieved by planting and in Alberta, as a consequence, the species leads in numbers of seedlings annually planted.

White spruce is classified as moderately tolerant of shading, as illustrated by the development of the species in the understory of aspen forests. Rapid growth, however, requires plenty of light and low competition.

Evolution and Genetic Variation Four other spruce species are native to Canada; two are found in Alberta, black spruce and Engelmann spruce. One hybrid individual of white spruce and black spruce has been identified (not in Alberta) and verified by careful analysis. Natural hybrids between these species, however, seem to be very unlikely.

In southwestern Alberta, as the elevation of spruce forests increases, the frequency of apparent natural hybrids with Engelmann spruce increases until trees are predominantly, or entirely Engelmann spruce. Morphological traits allow some discrimination between these species and molecular techniques have been developed to more precisely estimate the degree of genetic mixing in individuals. A variety reported from southern Alberta, *P. glauca* var. *albertiana* (S. Brown) Sarg. is believed to be the product of hybridization with Engelmann spruce.

Extensive genetic variation associated with geography has been identified in white spruce, as would be expected in a species represented in such a wide range of environments. Patterns of genetic variation generally have shown gradual change over distance although trees grown from seed collected in parts of Manitoba and eastern Canada have shown good survival and vigor in Alberta. A pattern of reduced vigor, as the elevation of seed collection increases, has been common. The transfer of seed from lower to higher elevation offers some potential for increased growth rate but transfers must be limited to avoid losses from damaging effects of a colder climate at higher elevations.

Large genetic differences among individual trees and substantial differences among populations within ecological zones have been identified. White spruce is being bred for improved growth rate and insect resistance in many tree improvement programs.

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

Family: Pinaceae

Photo: A.J. Gould

Photo: J.D. Johnson

Photo: J.D. Johnson

Species Characteristics Black spruce is a very narrow-crowned tree, often with a club-shaped top. It lives for up to 150 years. 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 2 to 3 cm long, dark brown to purple, and 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* (Moench) Voss) and Engelmann spruce (*P. engelmannii* Parry). Native peoples used powdered resin to speed healing of wounds.

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° North Latitude in the eastern portion of its range. In eastern Alberta, the southern limit of the species has been placed from a few miles north of Lloydminster, west to Smoky Lake and then southwest to the vicinity of Lake Louise. Black spruce has not been found in the river valleys that extend the range of white spruce to the southeast in the Central Parkland Natural Subregion nor is it present in the Cypress Hills.

The species often is associated with saturated organic soils and areas with permafrost although it is much more vigorous on soils with better drainage. On wet sites, its 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 lodgepole – jack pine hybrids following fire. On upland sites in the boreal, it is less common in mixed stands with white spruce, poplars (*Populus* spp.), jack pine (*Pinus banksiana* Lamb.) and hybrid pine.

Regeneration Black spruce reproduces naturally by seed and, to a much lesser extent, by the layering of branches. Good cone production generally begins at about 30 years of age with substantial crops at 2 to 6 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. Fire 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.

Black spruce is a minor reforestation species in Alberta where it is regenerated by natural seeding or planting. Planting has increased steadily over the past decade as utilization standards and full timber allocation have moved timber harvesting into less productive sites and stands.

Evolution and Genetic Variation Four other spruce species are native to Canada; two are found in Alberta, white spruce and Engelmann spruce. One hybrid individual of white spruce and black spruce has been identified (not in Alberta) and verified by careful analysis. Natural hybrids of black spruce with white or Engelmann spruce, however, seem to be very unlikely.

Genetic variation associated with geography follows patterns of gradual change that are correlated with changes in photoperiod and temperature. Genetic variation in black spruce from the western portion of the range has not been studied as intensively as in white spruce. After 15 years, genetic tests of populations representing much of the range of black spruce in Alberta have shown relatively small genetic differences and populations have not followed a consistent ranking in growth rate at different locations. Relationships between geographic origin of seed and variables such as latitude and elevation have been statistically significant only at some test sites. Large genetic variation among progenies from seed collected from individual trees has been reported.

The few programs of genetic improvement emphasize increased productivity in plantations and seed production in managed seed orchards.

Whitebark Pine (*Pinus albicaulis* Engelmann)

Family: Pinaceae

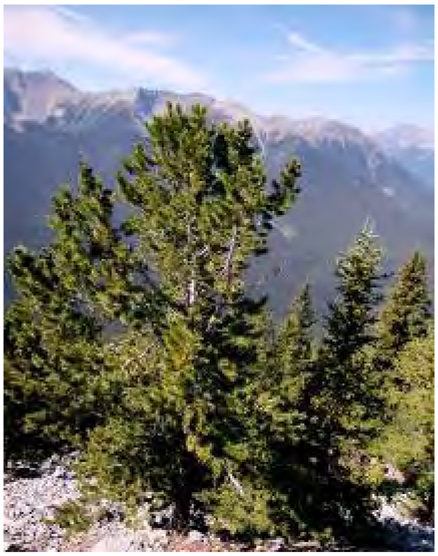
Photo: D. Vujnovic


Photo: D. Vujnovic


Photo: D. Vujnovic

Species Characteristics Whitebark pine is a small to medium-sized evergreen tree found at high elevations. It is often shrubby or multi-stemmed but may be single-stemmed in favourable locations where it can reach 20 m in height. At higher elevations it can form climax stands that may persist for 500 to 1000 years. Its common name refers to the smooth, light grey to white bark of young trees. The needles occur in bundles of five and are 5 to 10 cm long.

Whitebark pine is the only North American stone pine, a subsection of the pines whose cones remain closed at maturity and whose seeds are wingless. Male and female cones are borne on the same tree. The female cones are 4 to 8 cm long and develop near the ends of the upswept branches towards the top of the tree. Male cones are about 1 cm long and occur on new growth throughout the canopy. Limber pine (*P. flexilis* E. James), is a similar 5-needled pine that usually occupies a different range of habitats at lower elevations. The two species are best distinguished on characters of the cones.

General Ecology Whitebark pine has two distinct geographic distributions. One extends through the Cascade Mountains in British Columbia, Washington and Oregon, south to the Sierra Nevada of central California and the other follows the Rocky Mountain ranges from 54°N in B.C. to 41° N in western Wyoming. In the northern part of its range in Canada, whitebark pine often occurs in small, isolated populations on exposed ridges and talus slopes at elevations of up to approximately 2300 m, whereas in the more southern part of its range (in the US) it forms continuous forests on gentler topography.

In Alberta, whitebark pine ranges from Waterton Lakes National Park to approximately 150 km north of Jasper National Park on the British Columbia-Alberta border, in the Subalpine Natural Subregion of the Rocky Mountains Natural Region.

As an early seral species, it grows in both open- and closed-canopy stands, colonizing environments exposed by avalanche, glacial retreat or fire. It also occurs as small clumps or scattered trees in late succession stands of Engelmann spruce (*Picea engelmannii* Parry) and Rocky Mountain alpine fir (*Abies bifolia* A. Murray), or in early successional lodgepole pine (*Pinus contorta* var. *latifolia* Engelmann) stands.

Rocky Mountain alpine fir and Engelmann spruce occur with whitebark pine on wetter sites on moderate slopes, sometimes with a well-developed dwarf shrub–herb layer. On steep, well-drained slopes with significant bedrock exposure and bare mineral soils, it may associate with lodgepole pine or be the sole tree species associated with shrub layers of limited species diversity.

Whitebark pine is a keystone species in subalpine ecosystems. Several species rely on it for shelter and seeds are eaten by Clark's nutcrackers, bears, and red squirrels. Whitebark pine also plays an important role in watershed protection by binding soil and facilitating the return of vegetation to exposed mountain landscapes following disturbance.

Regeneration Whitebark pine is a long-lived species that relies almost entirely upon seed production for reproduction but does not usually produce cones until 25 to 30 years of age. The interval from cone initiation to seed maturity is about two years; masts of seeds produced every 3 to 5 years alternate with low seed output in the intervals.

Clark's nutcracker (*Nucifraga columbiana* Wilson) has evolved a mutualistic relationship with whitebark pine. These birds pry open the cone scales with their bills to obtain the large, nutrient-rich seeds and possess a unique adaptation in being able to store the seeds in a special pouch under their tongues. They cache the seeds in 2 to 3 cm of soil, often on open, southern exposures where snow depth in winter is minimal. Uneaten seeds in caches may germinate and establish as seedlings. Since the cones are indehiscent, even after fire, the tree is entirely dependent upon nutcrackers for seed dispersal. Seed caching is likely responsible for the clustered mode of growth exhibited by some populations, as it promotes the germination of several seedlings together.

Fire encourages whitebark pine regeneration by creating openings attractive for cache making and favourable to tree establishment. At higher elevations survival of whitebark pine may be limited by harsh edaphic and weather conditions.

Evolution and Genetics For taxonomic purposes, the genus *Pinus* is divided into three subgenera, five sections and 12 subsections (See Appendix 2 for classification of species in Alberta). White bark pine has affinities with other stone pines, which are grouped in the subsection *Cambria* (Loud.).

Genetic variation in growth and response to blister rust inoculation traits have been demonstrated in the United States. There, parents of progeny that have demonstrated resistance to blister rust are being established in orchards for seed production. Evidence of genetic adaptation to local environments, however, suggests that seed from resistant parents in the US might not be adapted to environments in Alberta. Studies in Wyoming and Alberta suggest considerable variation within populations, with individuals from within a cluster being more closely related than individuals from different clusters within the population.

Jack Pine (*Pinus banksiana* Lamb.)

Family: Pinaceae

Photo: A.J. Gould

Photo: MaryAnn Mochulski

Photo: MaryAnn Mochulski

Species Characteristics Jack pine is a relatively short-lived species (up to 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* Engelm.*)* is a similar species in Alberta.

General Ecology Jack pine grows further north than any other North American pine and its range extends from the Maritimes nearly to Yukon. In Alberta, it is the major forest species in the northeast where soils are predominantly coarse textured. In the northwest it is increasingly replaced by aspen due to the greater extent of finer-textured parent materials.

Where the ranges of jack pine and lodgepole pine overlap, mixtures of trees resembling each species and trees with characteristics intermediate between the two species (natural hybrids), are found.

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. In mixed stands, the most common associates are aspen (*Populus tremuloides* Michx.), white birch (*Betula papyrifera* Marsh.) and black spruce (*Picea mariana* (Mill.) B.S.P.).

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. Cones may remain closed for many years and fire is an important element in cone opening. Seed dispersal is mainly by wind and regeneration is most successful on mineral seedbeds.

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.

Seedling growth of jack pine is slow during the first few years, then rapid where nutrition, moisture and light are adequate.

Evolution and Genetics For taxonomic purposes, the genus *Pinus* is divided into three subgenera, five sections and 12 subsections (See Appendix 3 for classification of species in Alberta). The subsection containing jack pine (*Contortae)* has four species, all in North America but only two in Alberta. Apparent natural hybrids with lodgepole pine are common in areas where the distributions of the two species overlap in west-central Alberta. Hybrid jack pine populations have straighter stems and finer branches, tolerate a broader range of site types and are more desirable for commercial forestry. They may also have better pest resistance in comparison to the nearby pure lodgepole pine populations.

Large genetic differences associated with geography have been shown in several genetic tests. Seed originating near the test environment generally has produced the most vigorous trees although movement of seed northward up to 160 km has resulted in additional vigor. Large variation among provenances was found for early height growth in an Alberta study but geographic trends were not clear. 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.

A few programs of genetic improvement have been developed for jack pine. In Alberta, the tree improvement program emphasizes genetic improvements in stem and branch traits.

Lodgepole Pine (*Pinus contorta* var. *latifolia* Engelm.)

Family: Pinaceae

Photo: L. Allen

Photo: L. Allen

Photo: C. Crell

Species Characteristics Lodgepole pine is a medium sized tree with a tall, straight, clean stem. Although it is regarded as a relatively short-lived species, individuals older than 500 years have been reported. It reaches heights of 20 to 30 m or more and usually grows in dense, even aged stands. Occasionally it is found in open grown stands where it forms broad, bushy crowns. The bark is thin, orange-brown to grayish in colour and is finely scaled. Leaves are dark green to yellowish green and occur in bunches of two and are often twisted in a spiral with sharp points.

Seed cones and pollen cones are produced on the same tree and seed takes two seasons to mature. Seed cones are tan coloured, woody, ovoid or conical, 2 to 5 cm long, spreading or reflexed and have a sharp prickle at the edge of the seed scales. Jack pine (*P. banksiana* Lamb) is a similar species in Alberta.

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 and foothill outliers. Across the north it occurs at the highest altitudes in boreal hill systems where it is often closely associated with a band of hybrids with jack pine at intermediate elevations. A large isolated population is native to the Cypress Hills.

Associated species are Engelmann spruce (*Picea engelmannii* Parry) and Rocky Mountain alpine fir (*Abies bifolia* A. Murray). At lower elevations, western larch (*Larix occidentalis* Nutt.), aspen (*Populus tremuloides* Michx.), white spruce (*Picea glauca* (Moench) Voss), white birch (*Betula papyrifera* Marsh.) and in the south, Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) may be mixed in pine stands. Along a zone of overlap with jack pine in west-central Alberta, both parental species and various combinations of natural hybrids are common.

Lodgepole pine is most commonly associated with mountains and foothills where it can occupy both well-and poorly-drained soils including those of calcareous substrate. Fire often is a prominent feature in the origin of lodgepole pine stands. Tolerance of frost, poor soil drainage, and infertile soils convey competitive advantages to lodgepole pine over many associated species.

Regeneration Lodgepole pine regenerates only from seed. Seed production begins on trees at 5 to 10 years of age and good seed crops are frequent. Serotinuous (closed) cones are common but frequency of this characteristic is variable. Seeds held in cones are quite durable and have been shown to germinate after many decades. Natural regeneration is common following disturbance, especially fire. The practice of scarification is often used after harvest to expose mineral soil and to bring cone bearing branches closer to the soil so that high temperatures can prompt cone opening and seed release.

Natural regeneration of lodgepole pine is often abundant with many thousands of trees per hectare. Unlike many tree species, where some individuals overcome high stand density and develop at the expense of their neighbors, lodgepole pine may respond with very low vigor in a condition called “stagnation”.

Regeneration by planting is technically a well-developed procedure and is widely practiced, especially where genetically improved stock is available. Young lodgepole pine grows more rapidly than some of its associated species if adequate moisture is available and if there is an absence of competing vegetation.

Evolution and Genetics For taxonomic purposes, the genus *Pinus* is divided into three subgenera, five sections and 12 subsections (See Appendix 3 for classification of species in Alberta). The subsection containing lodgepole pine (*Contortae)* has four species, all in North America but only two in Alberta. Of the four varieties identified for lodgepole pine, *latifolia* is the only one found in Alberta.

Variation associated with geography has been well studied in lodgepole pine and the gradual patterns of genetic change with distance, especially elevation, are typical of those expected with species that are found across a wide range of environments. In Alberta, genetic studies have shown population variation related to elevation, differential performance among populations tested in different environments and variation among individual trees for growth and disease resistance.

Hybidization with jack pine occurs in a broad zone in west-central Alberta and in the tops of boreal hill systems in the north. Hybrids have been reported east as far as the Christina Highlands. Lodgepole pine has been reported at higher elevations in the north in the Birch, Caribou, and Pelican Mountains as well as in the Clear and Cameron Hills. Hybrids tend to occupy intermediate environments to the parental species following a pattern of increased ‘boreality’ related to decreasing longitude and altitude. Within the overlapping range, individual trees representing the range between the two species are common.

Hybridization with jack pine may have played a significant role in the evolution of pest resistance in lodgepole pine. A strong relationship has been reported between pest incidence of populations and their distance from the western edge of the natural distribution of jack pine; i.e., the closer a lodgepole pine population is to the natural range of jack pine, the higher is its resistance to pests.

Genetic variation within populations of lodgepole pine is being developed in many tree improvement programs, including several in Alberta.

Limber Pine (*Pinus flexilis* James)

Family: Pinaceae

Photo: H. Eijgel

Photo: MaryAnn Mochulski

Photo: A.J. Gould

Species Characteristics Limber pine is a small to medium-sized (12 to 26 m high) soft pine with a trunk diameter reaching 60 cm. It grows slowly but can live for several hundred years. In mature trees, the trunk is tapered and often twisted, with numerous branches extending for most of the bole's length. Young branches particularly are very tough and flexible, hence the species' name, undoubtedly an adaptation to the windswept habitats in which it occurs. The bark is pale grey, smooth in young trees and changes to rough, with scaly plates as the trees mature. The leaves, or needles, are clustered in bundles of five; they are 3 to 7 cm long and 1 to 1.5 mm wide, and have whitish lines of stomata that are more conspicuous on the upper surface than the lower.

Pollen cones and seed cones, which are narrowly ovoid and 8 to 20 cm long, develop on the same individual; the male cones in the lower part of the crown and the females in the upper. The seeds are virtually wingless. Whitebark pine (*P. albicaulis* E. James), is a similar 5-needled pine that usually occupies a different range of habitats at higher elevations. The two species are best distinguished on characters of the cones.

General Ecology Limber pine has an extensive but patchy distribution from the Rocky Mountains in southeastern British Columbia and western Alberta south as far as New Mexico, with scattered populations also farther to the west and in the Great Plains and the midwestern U.S. Its altitudinal range from 100 to 3600 m is also large.

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. Shade-intolerant, on forest sites it is usually a pioneer species that moves in after fire or tree removal. Species commonly associated with limber pine in Alberta are Interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) and whitebark pine. Limber pine is ecologically important in providing shelter and food for wildlife in exposed landscapes and for watershed protection.

Regeneration Reproduction is by seed, with good seed crops being produced every 2 to 4 years. Pollination occurs in late spring followed by fertilization almost a year later, although cones and seeds mature rapidly thereafter. The cones change from green to brown and seeds are dispersed in September or October.

Seeds are predominantly dispersed by Clark's nutcrackers (*Nucifraga columbiana* Wilson) and rodents. Clark's nutcrackers cache the seeds of this pine, as well as of whitebark pine, carrying up to 125 seeds per trip in their sublingual pouches. The seeds are usually buried in a cache of 1 to 5 seeds, on windswept ridges or southerly slopes where snow does not lie deeply. Limber pine has, in addition to single trunk and multi-trunk growth habits (single genotype or genet), a clustered form of growth, as a result of caching by nutcrackers. The clusters are typically made up of stems of genetically different (multi-genet) but related individuals. 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 For taxonomic purposes, the genus *Pinus* is divided into three subgenera, five sections and 12 subsections (See Appendix 3 for classification of species in Alberta). 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 "soft pines" in the Subgenus *Strobus*. No natural hybrids have been reported among these three species.

Range-wide variation has been documented in this species, for example, in wood compounds, and in the amount of overall genetic diversity. Except for the development of some varieties as bonsai trees, no commercial use has been made of this species because of its slow growth rate and contorted habit. The longevity of this tree makes it useful in dendrochronological studies.

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

Family: Pinaceae

Photo: A.J. Gould

Photo: A.J. Gould

Photo: C. Crell

Species Characteristics Western white pine is a large tree of western North America, however in Alberta it is limited to a few scattered trees in the southwest corner of the province. This evergreen conifer is generally a slender, columnar tree with whorls of relatively short, spreading branches borne on the upper two-thirds of the trunk; open-grown trees may have broader, more rounded crowns. The bark is grey and smooth in youth but furrowed and scaly-plated in older trees. The leaves are borne in bundles of five, enclosed by sheaths of basal scales, which fall off in the first year of growth. The leaves are 4 to 10 mm long, 0.7 to 1 mm wide and bluish-green with lines of white stomata on the undersides.

Both pollen and seed cones are produced on the same individual. The 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 in the upper part of the crown. The ripe cones are cylindrical, 10 to 25 cm, creamy brown, with the numerous woody scales each having a terminal projection or umbo. Two other 5-needled pines occur within the range of western white pine in western Canada: limber pine (*P. flexilis* James) and whitebark pine (*P. albicaulis* Engelm.).

General Ecology Western white pine has a coastal range from southern British Columbia to California and an interior one from British Columbia and Alberta through Idaho, western Montana and northeastern Oregon. It has a wide elevational range, from 0 to 3000 m, but in the Rocky Mountains it occurs between 500 and 1800 m where it favours valley bottoms and lower north-facing slopes in steep terrain. It grows on a variety of soils in varied habitats; like most pines it is characteristic of well-drained soils but actually grows best on deep, richer soils. In the mountains it is often found on open, rocky slopes but in its coastal range it can even grow in lowland bogs. It is a seral species but is usually found mixed with other conifers. A relatively shade-intolerant tree, it becomes dominant in a stand only after fire or silvicultural practices favouring it have taken place.

The species is prized commercially; the soft, light, non-resinous wood being used for a variety of purposes including construction, matchwood and home handicrafts.

Regeneration Regeneration is exclusively by seed under natural conditions. Trees aged from 7 to 20 years produce predominantly female cones, with heavy seed production occurring after about 70 years. It takes about two years from the initiation of cones to the production of ripe seeds, with pollination taking place in the spring and seed release in the fall one year later.

Seed dispersal is effected by wind and seed-eating animals and birds. The seeds require 1 to 4 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 For taxonomic purposes, the genus *Pinus* is divided into three subgenera, five sections and 12 subsections (See Appendix 3 for classification of species in Alberta). Of the five 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.

In contrast to most tree species, western white pine shows little genetic differentiation among populations and adaptation to a wide range of conditions is thought to be due to phenotypic plasticity. However, differences in cold hardiness have been found between coastal and interior populations in British Columbia and genetic variation is found within populations. Breeding trials indicate that height and resistance to white pine blister rust (*Cronartium ribicola* Fischer) are under genetic control.

Narrowleaf Cottonwood (*Populus angustifolia* James)

Family Salicaceae

 Photo: C. Crell	 Photo: C. Crell

Photo: C. Crell

Species Characteristics Narrowleaf cottonwoods are small trees growing to 15 m high and 30 cm 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 willows with which young saplings may be confused. Their smooth, whitish-green bark becomes furrowed at the base in mature trunks. The narrowly lanceolate leaves, 5 to 9 cm long, are again more typical of willows and readily distinguish this tree from other poplars, although not necessarily from riparian willows. 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 or 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 western/plains cottonwood (*P. deltoides* ssp. *monilifera* (Aiton) Eckenwalder).

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

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 is related to 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. As well, the shedding of branches that subsequently root provides another means of regeneration.

Evolution and Genetics The genus *Populus* is divided into six taxonomic sections (See Appendix 3 for classification of species in Alberta). Although there is not complete agreement on species names and section assignments, at least one other member of the section occupied by narrowleaf cottonwood, balsam poplar (*P. balsamifera* L.), is found in Alberta. Narrowleaf cottonwood is in the section *Tacamahaca* Spach of the genus *Populus*, and since this section includes the balsam poplars, it would more accurately be called narrowleaf balsam poplar. Another Alberta native, western/plains cottonwood is in a different section.

Although hybridization is generally most common among members of the same section, in southern Alberta, detailed analyses of both morphological and chemical traits indicate that balsam poplar, western/plains cottonwood and narrowleaf cottonwood interbreed freely and produce a single, trispecific hybrid swarm.

Genetic variation, other than as expressed in the many forms resulting from natural hybridization, has not been reported for narrowleaf cottonwood. Hybrids between narrowleaf cottonwood and western/plains cottonwood are classified as lanceleaf cottonwood, (*P.* x *acuminata* Rydberg).

Balsam Poplar (*Populus balsamifera* L.)

Family: Salicaceae

Photo: C. Crell

Photo: L. Allen

Photo: 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 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* Michx.*)* is a related species with an overlapping range in much of Alberta. Western/plains cottonwood (*P. deltoides* ssp. *monilifera* (Aiton) Eckenwalder) and narrowleaf cottonwood (*P. angustifolia* James) have ranges that overlap balsam poplar in southern Alberta.

General Ecology Balsam poplar is found from Newfoundland to Alaska. The principal range extends from the northern limit of trees to a southern boundary at about 35° North Latitude in the eastern part of North America. The distribution then follows a northwesterly pattern with a southern boundary at about 60° north latitude 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 Parklands Natural Subregion.

Balsam poplar often grows on flood plains, 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* (L.) Mill.), black (*Picea mariana* (Mill.) B.S.P.) and white spruce (*P. glauca* (Moench) Voss), aspen, and paper birch.

Balsam poplar is an early-successional species and is classed as very intolerant of shade.

Regeneration Balsam poplar is versatile in its form of reproduction. The minimum age for seed production is 8 to 10 years and on older trees, large quantities of seed are produced. Seed dispersal is by wind, and hairs attached to the seed provide support for long-distance travel. Seed has a short period of viability, however, and site requirements for successful seedling establishment are quite specific. Soil deposition after flooding may provide the seedbed that meets requirements for seedling establishment.

Balsam poplar can also regenerate from shoots developed on roots and stumps. Regeneration from root sprouts is common but sprouting is less prolific than for aspen. Of minor importance is regeneration from branch tips and branches that are broken from trees during disturbances from weather or harvesting.

Early growth is usually rapid. Root development along the buried stem can accommodate soil deposited by flooding. The result is a multi-layered root system.

Evolution and Genetic Variation The genus *Populus* is divided into six taxonomic sections (See Appendix 3 for classification of species in Alberta). Although there is not complete agreement on species names and section assignments, at least one other member of the section occupied by balsam poplar, narrowleaf cottonwood (*P. angustifolia* James), is found in Alberta. Another Alberta native, western/plains cottonwood (*P. deltoides* ssp. *monilifera* (Aiton) Eckenwalder) is in a different section.

Although hybridization is generally most common among members of the same section, in southern Alberta, detailed analyses of both morphological and chemical traits indicate that balsam poplar, western/plains cottonwood and narrowleaf cottonwood interbreed freely and produce a single, trispecific hybrid swarm. Hybrids between western/plains cottonwood and balsam poplar are classified as *P.* x *jackii* Sargent).

Although genetic differences among populations of balsam poplar in Alberta have not been studied, the few genetic studies conducted elsewhere demonstrate genetic differentiation in response to day length (latitude) and frost-free period (latitude and elevation).

Substantial genetic variation has been reported, among individuals and clones within populations. That genetic variation is being developed through tree improvement in one program in Alberta.

Western/Plains Cottonwood (*Populus deltoides* ssp. *monilifera* (Aiton) Eckenwalder)

Family: Salicaceae

Photo: A.J. Gould

Photo: L. Allen

Species Characteristics Western/plains cottonwood is a medium-sized to tall deciduous tree, reaching 30 m in height with a lifespan of 100 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. The male and female flowers are produced in similar catkins 5 to 7 cm long, but on separate individuals. The fruiting catkins reach 15 to 25 cm, and are composed of numerous green dehiscent capsules whose many seeds each bear a tuft of cottony hairs to aid in wind dispersal.

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

General Ecology Western/plains cottonwood is distributed westwards from southern Manitoba to southeastern Alberta, and southwards down through the Great Plains of the U.S. as far as northern Texas and northeastern New Mexico. Its eastern limit is not well defined where it intergrades with the eastern cottonwood. Western/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* L.).

Cottonwoods have enormous ecological value, providing cover and food for wildlife, including fish, along river systems. In addition, the shade they provide, their location and the fact that they create habitat for wildlife, provide important recreational opportunities for people.

Regeneration Western/plains cottonwood is flexible in its reproductive mode. Good seed crops are produced almost every year in trees aged ten years and older, and are widely dispersed by wind and water. Vegetative reproduction is by root sprouts and by sprouts from stumps. Despite the production of large quantities of seed, regeneration of stands by sexual reproduction occurs irregularly, at intervals of perhaps 5 to 10 years, because of the exacting conditions needed for seedling establishment.

Abundant soil moisture in the early stages of seedling establishment when growth of the roots is slow is particularly critical. 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 The genus *Populus* is divided into six taxonomic sections (See Appendix 3 for classification of species in Alberta). Western/plains cottonwood is one of the four poplar species in Alberta and the only one in the Section *Aigeros.* Although hybridization is generally most common among members of the same section, in southern Alberta, detailed analyses of both morphological and chemical traits indicate that western/plains cottonwood, balsam poplar (*P. balsamifera* L.) and narrowleaf cottonwood (*P. angustifolia* James) interbreed freely and produce a single, trispecific hybrid swarm.

Hybrids between western/plains cottonwood and balsam poplar are classified as (*P.* x *jackii* Sargent). Hybrids between western/plains cottonwood and narrowleaf cottonwood are classified as lanceleaf cottonwood (*P.* x *acuminata* Rydberg).

Western/plains cottonwood has not been the subject of much genetic study. Its close relative, eastern cottonwood, has shown substantial genetic variation among and within populations for a variety of traits. That variation has been the basis for extensive tree breeding in other jurisdictions.

Aspen (*Populus tremuloides* Michx.)

Family: Salicaceae

Photo: A.J. Gould

Photo: L. Allen

Photo: L. Allen

Species Characteristics Aspen is a medium-sized, relatively short-lived tree. The smooth grey-green to beige bark, with black patches, becomes furrowed as trees become older. Leaves are dark green above, pale green below, turning yellow in autumn before shedding. Leaves are nearly round with a sharply-pointed tip, a wavy margin and a flattened petiole. In aspen, pollen and seeds are produced on different trees in catkins containing many flowers. Seeds, shed in spring, have long white hairs attached and disperse for long distances in wind. Balsam poplar (*P. balsamifera* L.) is a related species with an overlapping range in much of Alberta. Western/plains cottonwood (*P. deltoides* var. *occidentalis* Rydb.) and narrowleaf cottonwood (*P. angustifolia* James) have ranges that overlap aspen in southern Alberta.

General Ecology Aspen is the most widely distributed tree in North America with a range extending into Mexico. The species is found in much of Alberta although distribution in the southeast is scattered. In the Central Parkland Natural Subregion, aspen is the dominant tree species and commonly exists in stands of stunted trees 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 white birch (*Betula papyrifera* Marsh.); occasionally with Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) in the montane. As succession progresses, aspen is increasingly reduced by conifers with more shade tolerance such as white spruce (*Picea glauca* (Moench) Voss), black spruce (*Picea mariana* (Mill.) B.S.P.) and balsam fir (*Abies balsamea* (L.) Mill.).

Young aspen stands provide habitat and food for many different species of animals. As a consequence of low accumulation of woody fuels, aspen stands also serve as natural firebreaks.

Regeneration Seed production in aspen is common, and seeds can be carried for long distances as a consequence of the white hairs attached to each seed. Seed has a short period of viability, however, and site requirements for successful seedling establishment are quite specific.

The maintenance of aspen as a component of forests is mainly by root sprouts. Sprouts develop from root systems of individual trees in a sequential manner that results in a somewhat dome-shaped assemblage of trees. Where such assemblages arise from a single tree, the individuals are all considered to have the same genes and, thus, constitute a clone. When apical dominance is released through destruction of the existing stems, or through damage to root systems, large numbers of sprouts emerge. Aspen is widely harvested and regeneration is typically from the sprouts that follow. Although nursery culture of aspen from seed is well understood, the ease of obtaining regeneration from sprouts makes planting generally unnecessary.

Aspen is capable of very rapid growth where nutrients and a suitable level of moisture are available.

Evolution and Genetic Variation The genus *Populus* is divided into six sections for taxonomic purposes (See Appendix 3 for classification of species in Alberta). The section containing aspen is represented by two species in North America but only by aspen in Alberta. Natural hybrids between aspen and other native poplars in Alberta have been reported. Detailed analyses of the natural hybrids reported in southern Alberta indicate that aspen, however, is not represented in the hybrid complex of that region. Artificial hybrids of aspen with other species of poplar native to Alberta have been produced, but natural hybridization of aspen is not considered to be a significant feature of the species in Alberta.

The reproductive modes of aspen offer unusual opportunities for perpetuating the species. Where suitable seedbeds are available, reproduction by seed allows new combinations of genes to be tested. Where highly successful combinations occur, reproduction by root sprouts can maintain those combinations. Although individual trees are not typically long-lived, clones have the potential to live for many centuries.

Genetic variation associated with geography has been demonstrated indicating adaptation to environmental gradients. Gender differences related to environmental gradients have also been demonstrated with the proportion of males increasing with elevation and in harsher environments. In more suitable environments, sex ratios are closer to equal but female growth performance has been shown to be superior across environments.

Comprehensive testing of populations of interest to Alberta is in the very early stages. Aspen is recognized as one of the most variable tree species with large genetic and phenotypic differences between clones for a wide range of traits.

Interspecific hybrids of aspen with non-native poplar species of the same section are of commercial interest for their rapid growth. A program of genetic improvement for aspen in Alberta is in progress. As yet, improved materials in sufficient quantities for reforestation have not been produced.

Interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco)

Family: Pinaceae

Photo: H. Lazaruk

Photo: L. Allen

Photo: L. Allen

Species Characteristics Interior Douglas-fir, sometimes called Rocky Mountain Douglas-fir, is a medium-sized tree with thick, deeply furrowed bark. It can live for several hundred years. Leaves are 2 to 3 cm long and spirally arranged, though appearing to be two-ranked as a consequence of twisted needle bases. Winter buds are sharp-pointed. Seed and pollen cones are borne on the same tree. Seed cones are 5 to 10 cm long, upright initially but becoming pendant after pollination. Bracts extend beyond cone scales. There are no similar species in Alberta.

General Ecology Interior 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. In addition to the main distribution, there are many scattered stands south and east of Idaho.

The species is at its most northeastern limit in parts of southwestern Alberta and is characteristically a species of the montane zone. Outlier populations can be found along river valleys stretching eastward from the Rocky Mountains and on steep southern grassy slopes and cliff faces in the southern subalpine.

Interior Douglas-fir typically occupies warmer, drier sites than associated montane species and is limited within its natural range in Alberta by frost, short growing seasons, cold winters and occasionally, drought. It does not tolerate saturated soils but has a high tolerance of calcareous soils that are not uncommon in the montane. 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 in the montane, interior Douglas-fir, through longevity, maintains a successional climax type. In Alberta, this is most notable in the Porcupine Hills where it is a co-climax species with white spruce (*Picea glauca* (Moench) Voss) and at higher elevations, its hybrids with Engelmann spruce (*P. engelmannii* Parry). Its most common associates in Alberta are lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.), aspen (*Populus tremuloides* Michx.), white spruce, hybrid spruce and at higher altitudes, Rocky Mountain alpine fir (*Abies bifolia* A. Murray).

<u>Regeneration</u> Interior Douglas-fir naturally regenerates from seed. The minimum age for seed production is about 20 years and peak production can be at ages of 150 to 200 years. Natural regeneration is favored by partial shade and interior Douglas-fir is classed as medium in shade tolerance. This allows it to persist and grow below the main canopy of aspen and open grown conifer stands within its Alberta range.

<u>Evolution and Genetic Variation</u> Two species of Douglas-fir are present in North America but only one occurs in Alberta. The species native to Alberta is a variety often called interior Douglas-fir to distinguish it from the variety (*P. menziesii* var. *menziesii* (Mirb.) Franco) that is a well-known component of the Pacific coast forests. Interior Douglas-fir has no known hybrids with other species but interior and coastal varieties cross naturally where the two meet and artificial hybrids between the two varieties are easily produced.

Genetic variation among populations of interior Douglas-fir has been widely studied. Patterns of variation associated with geography show gradual genetic change across latitude and longitude, but rapid genetic change with change in elevation. The patterns are interpreted to reflect a balance between high growth potential in mild environments and high cold hardiness in cold environments. Limited genetic testing of Alberta populations in southwestern Alberta confirms this same pattern. Populations from higher elevations and the foothills in the south were slower growing but hardier than provenances originating in montane river corridors from Canmore north. In early testing, there was a strong inverse correlation between height growth potential and survival. Of interest is the fact that best survival and growth occurred on a site established outside its natural range along the North Saskatchewan River north of Rocky Mountain House.

Large genetic differences for many traits have been identified among trees within populations and these differences serve as the basis for many tree improvement programs. A small tree improvement program has been established in Alberta.

Peachleaf Willow (*Salix amygdaloides* Andersson)

Family: Salicaceae

Photo: L. Allen

Photo: L. Allen

Species Characteristics Peachleaf willow is unusual among the willows (*Salix* spp.) in reaching tree size (up to 20 m in height, and 40 cm in diameter). It is the tallest willow in the prairie provinces. It can often have several trunks, however, 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, 5 to 14 cm long, and taper to a long, pointed tip. They are bright yellow-green above and whitish or glaucous beneath. The stipules, which are a useful diagnostic character in willows, are absent or inconspicuously minute. Pollen and seed catkins are about 3 to 6 cm long, and produced on leafy branchlets on separate individuals like in all other willows. The pollen catkins are unusual in having 4 to 7 stamens, most commonly 5. Peachleaf willow could be confused with other willow species that occur in similar habitats, namely along riverbanks, particularly yellow willow (*S. eriocephala* var. *famelica* (C.R. Ball) Dorn), 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. 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 the floodplain, or grow mixed with cottonwoods (*Populus* spp.) and other willows. In providing cover, shade, nesting opportunities and food for birds and insects, it is a very important component of riparian ecosystems in the plains. In providing cover, shade, nesting opportunities and food for birds and insects, it is a very important component of riparian ecosystems in the plains.

Regeneration Peachleaf willow regenerates by seed and from fragmented branches. Pollination is effected both by wind and insects. The fruiting catkins bear glabrous 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 (See Appendix 3 for classification of species in Alberta).

Genetic variation has not been studied in the species. Its wide range, however, would lead to an expectation of substantial genetic variation.

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

Family: Salicaceae

Species Characteristics Scouler's willow is a large shrub or small tree, often crooked in stature, that grows to 9 to 12 m high. It has a grey, smooth bark that becomes fissured in older stems and develops the diamond-shaped scars characteristic of some willow (*Salix*) species. The greenish-brown twigs are hairy when young. The leaves, 5 to 12 cm 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 10 mm long, the longer stipules being found on vigorous shoots.

The catkins are precocious (*i.e.*, appearing before or at the time of leaf flushing) and without stalks; pollen catkins are 2 to 4 cm long and bear male flowers with two stamens. Seed catkins (2 to 6 cm long) are borne on separate individuals. The capsules of the fruiting catkins are 5 to 8 mm long and densely grey-hairy. Scouler's willow resembles a number of other willows but in the field, it is perhaps most likely to be confused with plane-leaved willow, *S. planifolia* Pursh.

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. Its habitats are dry coniferous woods, floodplains and sandy beaches or sand dunes.

All willows have an ecologically important role, providing food and cover, particularly for insects and birds.

Regeneration No information was found on regeneration of Scouler's willow. Presumably, regeneration is mostly by seed as in other willow species.

Evolution and Genetics Scouler's willow is one of many willow species but only two are found as trees in Alberta (See Appendix 3 for classification of species in Alberta).

Genetic variation has not been studied in this species. Its wide range, however, would lead to an expectation of substantial genetic variation.

Western Yew (*Taxus brevifolia* Nuttall)

Family: Taxaceae

Photo: A.J. Gould

Photo: A.J. Gould

Species Characteristics Western yew is an evergreen coniferous tree or shrub, reaching usually no more than 15 m in height and having a trunk diameter of up to 60 cm. It is slow-growing but may live for several hundred years. The crown is open-conical or irregular, typically with a central straight stem, and the trunks of older trees may be obviously fluted and twisted. The thin, reddish-bark is smooth in youth but scaly in age. The leaves, which are linear and flattened, with a pointed but soft tip, are from 1 to 3 cm long. Green above, they are paler on the lower surface where two broad bands of stomata are located. They are inserted in two ranks along characteristically green twigs.

The pollen cones are globose with about 4 to 12 scales, and are borne in profusion on the undersides of twigs on male trees. The seed cones are fewer in number and also occur on the undersides of twigs, but on female trees. They each produce a single seed that is enveloped in a red, fleshy, cup-shaped structure or aril, the familiar yew "berry." Although the foliage, bark and seeds of most yew species are toxic owing to the presence of the alkaloid taxine, this has not been found in western yew. The other yew species in Canada, Canada yew, (*T. canadensis* Marshall), 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. Here 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* Parry) and Rocky Mountain alpine fir (*Abies bifolia* A. Murray).

The reddish wood is hard and durable and has a variety of specialty uses. This tree is also the source of taxol, a potent anti-cancer drug. Until the development of a synthetic taxol, there was the possibility that in some parts of the species range, over-harvesting could create a threat to populations.

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, but both birds and rodents are responsible for seed dispersal. Rodents and some bird species cache the seeds, which may give rise to the clusters of seedlings sometimes seen. 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 This species was originally classified as the European yew (*T. baccata* L.), and an early classification of what are now considered seven species worldwide was to treat them as varieties of *T. baccata*. Distinguishing the species is difficult and is based mainly on distinct geographic ranges.

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

Family: Cupressaceae

Photo: C. Crell

Photo: A.J. Gould

Species Characteristics Western redcedar is a long-lived, coniferous tree that can live for 800 years or more. It is a large tree in much of its range. The species is at the extreme eastern edge of its distribution in Alberta, however, and varies here from a shrub to a small tree. The crown is conical, with arching branches and pendulous branchlets forming fan-shaped sprays. Young trees have reddish- or grayish-brown smooth bark which becomes fibrous and fissured with age. Leaves are of two types: awl-shaped leaves occur on larger branchlets or juvenile trees and are 4 to 5 mm long, and scale leaves, only 1 to 2 mm long, occur on the flattened, lateral branchlets and are crowded and appressed. All leaves are arranged in four ranks and are glossy-green on top, but with white stomata on the undersides that give a silvery appearance to the undersides of the branchlets.

The reddish pollen cones (1 to 3 mm long) and green (later brown) seed cones are produced on different branches of the same tree, the males on the lower branches and the females towards the top of the crown. The ovoid or ellpsoid seed cones are 10 to 14 mm long, with 4 to 10 paired scales. There are no similar species in Alberta.

General Ecology This cedar has two ranges: a coastal one extending from southeast Alaska to northwest California, and an interior range along the Rocky Mountains from British Columbia and Alberta to Idaho and Montana, with a few scattered stands forming a connection between the two in southern British Columbia. For Alberta, most records are from the Crowsnest Pass area of southwestern Alberta, although scattered occurrences are noted as far as north of Willmore Wilderness Park. Western redcedar occurs mostly in moist sites, in mixed coniferous forests rather than in pure stands, and from altitudes of 0 to 2200 m, although at altitudes above 1500 m and in harsh environments it can be shrubby. It will grow on a wide variety of soils, from moist alluvial to rich dry soils, and including those relatively low in nutrients such as sphagnum bogs.

It occurs in all stages of seral succession as its seeds establish on disturbed areas, but it is also characteristic of later-stage forests due to its competitive ability, shade tolerance and capacity for vegetative reproduction. It is generally thought of as a component of climax vegetation. In its Canadian range it may be associated with western hemlock (*Tsuga heterophylla* (Rafinesque) Sarg.), and at higher elevations with Rocky Mountain alpine fir (*Abies bifolia* A. Murray), western larch (*Larix occidentalis* Nutt.), Engelmann spruce (*Picea engelmannii* Parry), white spruce (*P. glauca* (Moench) Voss), and lodgepole pine (*Pinus contorta* Doug. ex Loud.).

The heartwood of redcedar is extremely resistant to decay, and its wood has many uses in construction, including for roofing and fence posts. Perfumes, insecticides and deodorants are made from cedar leaf oil. Native North Americans used the tree extensively for the construction of lodges, canoes and clothing.

Regeneration Western redcedar reproduces mainly by seed and occasionally by layering, rooting of fallen branches and by branch development on fallen trees. Cones are produced after about ten years of age and every other year thereafter. 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 by birds or rodents, but seedling mortality can be high at the time of germination. In the northern Rocky Mountains, natural regeneration occurs best on slopes with western and northerly aspects.

Partial shade is helpful in seedling establishment and western redcedar is classified as a very shade tolerant species. Although growth rate is higher in sun than shade, growth rates, at best, are slower than for most associated tree species.

Evolution and Genetics Two species of the genus are found in North America, but western redcedar is the only one in Alberta. No natural hybrids of this species are known. Isozyme and seedling transplant studies indicate that genetic variation in western redcedar is low. For example, leaf oil terpene composition is similar among trees from low and high elevations in British Columbia and the various western states, although small differences have been found in some chemical characteristics between coastal and interior populations. Inland populations are also known to be more tolerant of frost.

Genetic variation among individuals provides a basis for genetic improvement programs in some coastal areas.

Western Hemlock (*Tsuga heterophylla* (Rafinesque) Sargent)

Family: Pinaceae

Species Characteristics Western hemlock is generally a tall, evergreen conifer, with a narrow crown, reaching heights of about 50 m and with a trunk diameter of up to 2 m. 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 1 to 2 cm long, 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 1.5 to 2.5 cm long with cone scales that are rounded and golden brown at maturity.

General Ecology Western hemlock is a tree of moist climates. With both coastal and northern Rocky Mountain ranges, it has an altitudinal spread from 0 to about 1500 m. 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 good organic layer. 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 Rocky Mountain alpine fir (*Abies bifolia* A. Murray) and Engelmann spruce (*Picea engelmannii* Parry), as well as lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.). 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 quite easily. Full seed production occurs in trees 25 to 30 years old and mast crops are produced at intervals of 2 to 8 years. Seeds ripen by mid to late September and, if the weather is very wet, seeds may be retained by closing of the scales. Western hemlock is a prolific seed producer although seed viability can be less than 50%. Seeds remain viable only during the first growing season after release.

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 (nurse trees). Some vegetative reproduction occurs by layering, and in the nursery trade, regeneration is effected easily from cuttings.

Evolution and Genetics Western hemlock is the only one of three North American hemlock species found in Alberta. Albino trees (deficient in chlorophyll) have been observed in the wild.

Although genetic variation has not been studied in Alberta populations, the species, especially in its coastal distribution is known to be genetically variable both among and within populations. Several programs of genetic improvement are proceeding elsewhere.

Appendix 2. List of Tree Taxa Naturally Occurring in Alberta with Associated Provincial/Sub-national (SRANK) and Global (GRANK) Ranks

(SRANK as per ANHIC 2006; GRANK as per NatureServe 2004). For the explanation of provincial and global ranks, please see Appendix 4.

Scientific Name	**Common Name**	**SRANK***	**GRANK**
Abies balsamea (L.) Mill.	balsam fir	S5	G5
Abies bifolia A. Murray	Rocky Mountain alpine fir	S4	G5
Acer negundo L.	Manitoba maple	S2?	G5
Betula neoalaskana Sargent	Alaska birch	S5	G4G5
Betula occidentalis Hooker	water birch	S4	G4G5
Betula papyrifera Marsh.	white birch	S4	G5
Juniperus scopulorum Sargent	Rocky Mountain juniper	S3	G5
Larix laricina (Du Roi) K. Koch	tamarack	S5	G5
Larix lyallii Parlatore	subalpine larch	S4	G4
Larix occidentalis Nutt.	western larch	S2	G5
Picea engelmannii Parry	Engelmann spruce	S5	G5
Picea engelmannii x glauca	Engelmann x white spruce	SNR	GNA**
Picea glauca (Moench) Voss	white spruce	S5	G5
Picea mariana (Mill.) B.S.P	black spruce	S5	G5
Pinus albicaulis Engelmann	whitebark pine	S2	G4
Pinus banksiana Lamb.	jack pine	S5	G5
Pinus contorta var. latifolia Engelm.	lodgepole pine	S5	G5
Pinus x murraybanksiana Righter & Stockwell	lodgepole x jack pine	SNR	GNA**
Pinus flexilis James	limber pine	S2	G5
Pinus monticola Douglas ex D. Don	western white pine	S U	G5
Populus angustifolia James	narrowleaf cottonwood	S3	G5
Populus balsamifera L.	balsam poplar	S5	G5
Populus deltoides ssp. monilifera (Aiton) Eckenwalder	Western/plains cottonwood	S3	G5
Populus tremuloides Michx.	aspen	S5	G5

Scientific Name	**Common Name**	**SRANK***	**GRANK**
Populus x acuminata Rydberg	lanceleaf cottonwood	S2	GNA**
Pseudotsuga menziesii var. glauca (Beissn.) Franco	interior Douglas-fir	S4	G5
Salix amygdaloides Andersson	peachleaf willow	S3	G5
Salix scouleriana Barratt ex Hook.	Scouler's willow	S4	G5
Taxus brevifolia Nuttall	western yew	S1	G4G5
Thuja plicata Donn ex D. Don	western redcedar	S1S2	G5
Tsuga heterophylla (Rafinesque) Sargent	western hemlock	S1	G5

* *Both provincial and global ranks are subject to periodic updates – check the Alberta Natural Heritage Information Centre (ANHIC) website (http://tpr.alberta.ca/parks/heritageinfocentre/default.aspx) for updates on provincial ranks and NatureServe website (http://www.natureserve.org/explorer/) for updates on global ranks.*

* * *NatureServe does not rank hybrids.*

Appendix 3. Sub-family Classification for Selected Genera

Species	**Sub-family**	**Sub-genus**	**Section**	**Subsection**
***Betula*[1]**				
B. neoalaskana	*Betuloideae*	*Betula*		
B. occidentalis	*Betuloideae*	*Betula*		
B. papyrifera	*Betuloideae*	*Betula*		
***Pinus*[2]**				
P. albicaulis		*Strobus*	*Strobus*	*Cembrae*
P. banksiana		*Pinus*	*Pinus*	*Contortae*
P. contorta		*Pinus*	*Pinus*	*Contortae*
P. flexilis		*Strobus*	*Strobus*	*Strobi*
P. monticola		*Strobus*	*Strobus*	*Strobi*
***Populus*[3]**				
P. angulata			*Tacamahaca*	
P. balsamifera			*Tacamahaca*	
P. deltoides			*Aigeiros*	
P. tremuloides			*Populus*	
***Salix*[4]**				
S. amygdaloides		*Salix*	*Humboltianae*	
S. scouleriana		*Vetrix*	*Cinerella*	

[1] *Furlow, J.J. 1997. Betulaceae Gray. In Flora of North America North of Mexico. Flora of North America Editorial Committee (Ed.) p. 507-538.*

[2] *Little, E.L., Jr., and W.B. Critchfield. 1969. Subdivisions of the genus Pinus (Pines). USDA Forest Service, Washington, D.C., Misc. Pub. No. 1144, 51pp*

[3] *Eckenwalder, J.E. 1996. Systematics and evolution of Populus. In Biology of Populus and its implications for management and conservation. Part I, Chapter 1. Ed. by R.F.Stettler, H.D. Bradshaw, Jr., P.E. Heilman and T.M. Hinckley. NRC Research Press, National Research Council of Canada, Ottawa, ON Canada. Pp. 7-32.*

[4] *Argus, G. 1997. Infrageneric classification of Salix (Salicaeae) in the new world. Systematic Botany Mono. 52: 1-21.*

Appendix 4. Definitions of Provincial/Sub-national (S) and Global (G) Ranks for Rarity of Taxa

This table was developed by NatureServe[5] and modified from Vujnovic and Gould. 2002[6].)

Rank	Definition
S1 G1	≤ 5 occurrences[7] or only a few remaining individuals
S2 G2	6-20 occurrences or with many individuals in fewer occurrences
S3 G3	21-100 occurrences, may be rare and local throughout its range, or in a restricted range (may be abundant in some locations or may be vulnerable to extirpation because of some factor of its biology)
S4 G4	Apparently secure under present conditions, typically 100 occurrences but may be fewer with many large populations; may be rare in parts of its range, especially peripherally.
S5 G5	Demonstrably secure under present conditions, > 100 occurrences, may be rare in parts of its range, especially peripherally.
SU GU	Status uncertain, often because of low search effort or cryptic nature of the element; possibly in peril, unrankable, more information needed.
S? G?	Not yet ranked.
_?	Rank questionable.

[5] *NatureServe. 2004. http://www.natureserve.org/explorer/*

[6] *Vujnovic, K. and J. Gould. 2002. http://www.cd.gov.ab.ca/preserving/parks/anhic/flashindex.asp*

[7] *The definition of occurrence is specified in an Element Occurrence Specifications Record and may vary from element to element but generally constitutes an area occupied by that element. Element Occurrence Specifications may specify minimum separation distance between locations of the element before they can be considered as separate occurrences.*

Appendix 5. Standards for Tree Improvement (STIA) for *in Situ* Gene Conservation

20.2 Between two and four areas of *wild* forest populations (as represented by species and stratum class, e.g. timber productivity rating, timber type) are required to be designated for gene conservation for each tree species included in a CPP Plan, in each *seed zone*,for which at least 15% of its gross area lies within the *Breeding Region* for that CPP plan. A single area may provide conservation for more than one species. The number of gene conservation areas required will depend on the area of *seed zone* contained within the breeding region as follows:

Seed Zone Size	Number of Conservation Areas Required
> 1.0 million ha	4 per species
0.5 – 1.0 million ha	3 per species
< 0.5 million ha	2 per species

Where less than 15% of a *seed zone* lies within the specified *Breeding Region*, gene conservation areas are not required.

For sizes of specific *seed zones*, see Appendix 7.

These gene conservation areas may be chosen from:

20.3 existing reserves, OR

20.4 subjective landbase deletions (e.g. streamside buffers, non-merchantable, inoperable), OR

20.5 harvestable areas dedicated for natural regeneration (e.g. natural seeding, partial cutting, plant with seed specifically from the site, or *wild Stream 1* collections from adjoining areas), OR

20.6 understory protection and variable retention areas (retain some naturals, supplement with planting with seed specifically from the core area [see Appendix 4] or if not available, *wild Stream 1* collections from adjoining areas).

20.7 *In situ* gene conservation areas will be implemented as follows:

20.7.1 Areas designated for gene conservation will be dispersed across the *seed zone* to minimize risk of loss.

20.7.2 Areas designated for gene conservation will be chosen with consideration for long-term protection from biological and non-biological threats. A CNT (Consultative Notation) is recommended for these areas.

20.7.3 Areas will be large enough to meet a reasonable expectation of 5000 trees (at rotation) in a core area with an additional buffer of 500 m around it.

20.7.4 The target species as identified in the CPP Plan will be managed as per the options specified in Standards 20.2 and 21.1.3.

20.8 For a given species, in any *seed zone* where *Stream 2 material* is being planted, the CPP plan(s) will indicate how *in situ* standards are being met. Because *breeding regions/deployment zones* may include more than one *seed zone* and more than one cooperator, cooperative planning among parties in each *breeding region/deployment zone* may be required.

21.1.3 Areas designated for gene conservation will be described in the DFMP, which will also include a statement of intended management on a time horizon of two rotations.