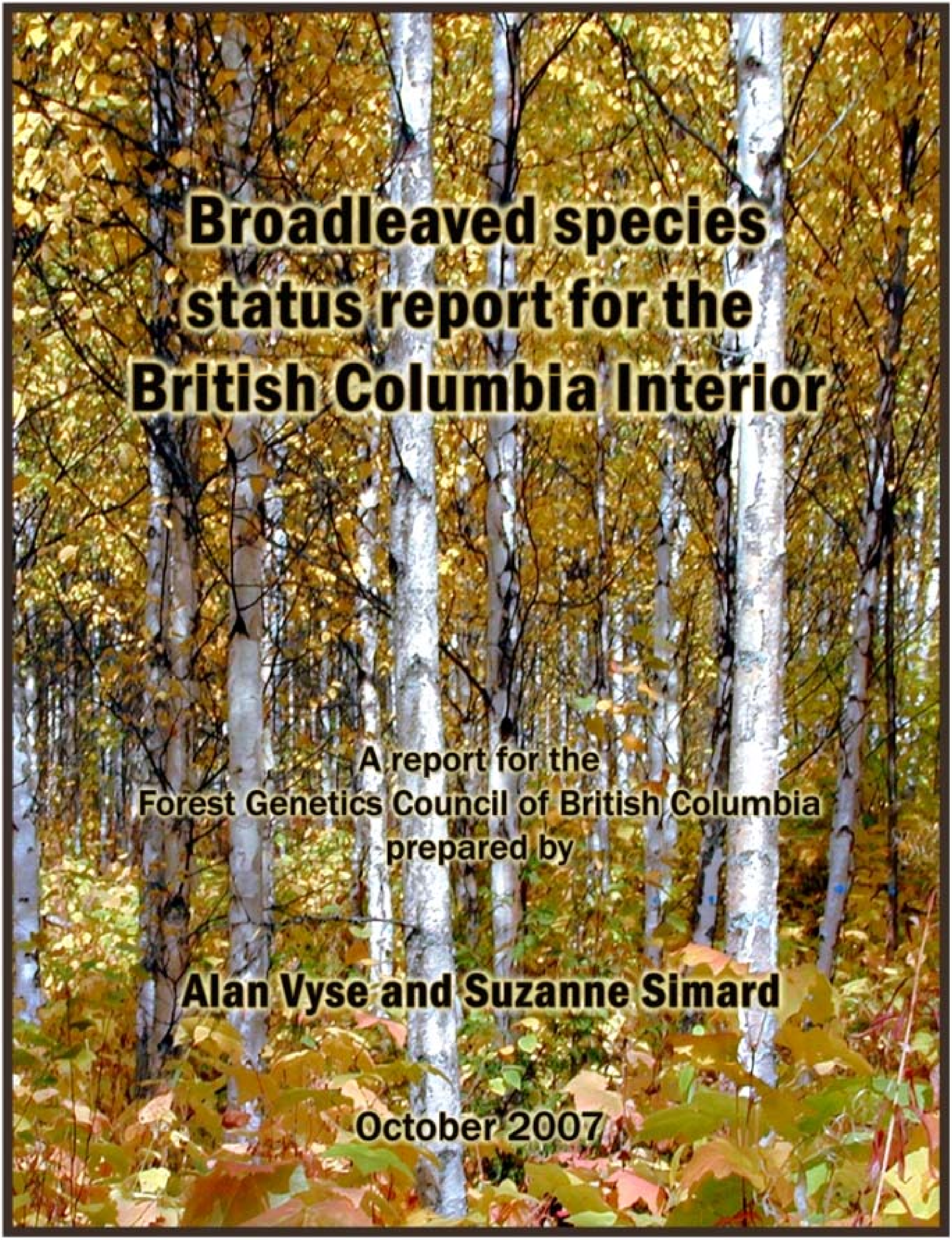

Broadleaved species status report for the British Columbia Interior

A report for the
Forest Genetics Council of British Columbia
prepared by

Alan Vyse and Suzanne Simard

October 2007

Cover photograph of the Lee Creek paper birch thinning trial by Barbara Zimonick

Broadleaved species status report for the British Columbia Interior

A report for the Forest Genetics Council of British Columbia

Prepared by

Alan Vyse, Emeritus Scientist, B.C. Forest Service and Adjunct Professor, Department of Natural Resource Sciences, Thompson Rivers University

and

Suzanne Simard, PhD, Associate Professor, Faculty of Foresty, University of British Columbia.

February 2008 (revised)

Executive Summary

We were asked to prepare a status report on broadleaved species in the Interior of B.C. by the Forest Genetics Council and to make recommendations on the future of forest genetics programs for these species.

The principal broadleaved species in the Interior of British Columbia (trembling aspen, paper birch, and the sub-species balsam poplar and cottonwood) are well distributed across all of the major Interior ecological zones but their occurrence is greatest in the northern areas. Their utilization has gradually increased over the last twenty years, especially in the Peace River District, but there is considerable potential for further increases. Economic values are low when compared to conifer species but this could change in the future. Shortage of conifer timber as a result of the mountain pine beetle epidemic could drive demand higher. In contrast, the ecological and non-timber values of broadleaves are very high throughout the Interior. This has been recognized, and as a result, retention of broadleaves in harvesting and reforestation programs is widely implemented. However the retention is practiced at a very low intensity.

There is a large volume of scientific information that can be applied to the management of broadleaves, should more intensive management begin, and this is amplified by numerous local silvicultural research trials in the Interior. The literature on the genetics of poplar is substantial but practical gene conservation and tree improvement for all broadleaved species is limited, and particularly so for balsam poplar.

The prospects for widespread deliberate management for broadleaves in the near future are not good. While there is some emphasis on management for aspen in the Peace River country, activities featuring broadleaves are rare elsewhere, despite their rapid growth in many ecosystems and many other advantages. Management practices that favour conifer species are a significant barrier to efforts aimed at advancing the wider use of broadleaves in the design of future forests.

Including broadleaves in mixed stands or in mixed landscapes is expected to conserve biodiversity and buffer forests against conifer host-specific disturbance, and may also mitigate the effects of fire, which is expected to increase in extent and severity with climate change. Species-rich mixed forests may also provide essential corridors for species migration northward during climate change. A mosaic of management pathways has been proposed where conifer enrichment, no intervention or intensive management of conifers and broadleaves could be applied on the Interior landscapes. However the proposed pathways would be based largely on natural regeneration of broadleaves and not nursery production which would permit introduction of improved strains of broadleaved species. There are two possible exceptions: there may be greater use of artificial regeneration of *Populus* or *Salix* hybrids for biofuel production on farmland in the Peace River; and the use of paper birch planting stock for root disease mitigation may increase in the Southern Interior plantations.

Given the current limited prospects for intensive broadleaved management, we do not recommend any large expansion of tree improvement work in any of the broadleaved species in the short term, but we suggest that the situation should be reviewed again in five years time . We do recommend continuation and strengthening of the existing programs in gene conservation and genecology for birch and cottonwood, and the addition of programs for aspen and balsam poplar in preparation for the eventual acceptance and much wider use of broadleaved species in Interior forest management.

Acknowledgements

Much has already been written about the occurrence of broadleaved tree species in British Columbia, most recently by Douglas et al. (1998, 2000); Brayshaw (1996); and Klinka et al. (2000). The silviculture of these species on their own, and in mixtures with conifers, has been dealt with by Simard and Vyse (1992, 2006), Peterson et al. (1997), Peterson and Peterson (1996), Comeau et al. (1996), and Comeau and Thomas (1996). Management and marketing of the products of broadleaved species has been described in some detail by Massie et al. (1994), and most recently by Royal Roads (2006). All of this material has provided an excellent base for preparing this status report. We are indebted to the earlier work of our colleagues for their willingness to share their views on the management of broadleaved species so freely. Jean Roach was responsible for the literature review. We also thank Barbara Zimonick for providing the image of the Lee Creek paper birch thinning trial.

Introduction

Broadleaved species[1] play a major role in the landscape and culture of Canada. The maple leaf is our national symbol and maple syrup satisfies the sweet tooth of the country. Paper birch provides another vivid example. It is a revered species in the culture of the First Nations living in the boreal forest … "the bright tree of life and legend" (Peterson et al. 1997; North House Folk School 2007) and in British Columbia (Turner 1979).It has alos made its mark more recently. The birchbark canoe was recently declared one of the seven wonders of Canada and generations of school children in Canada have learned the folk song "Land of the Silver Birch", with its evocative lyrics recalling canoeing in the woods of the Canadian Shield.

In our Pacific Province there is a twist to the national picture. Although the Pacific dogwood is the Provincial floral symbol, western redcedar is the Provincial tree. Broadleaves have long played "second fiddle" to the conifers that are so abundant across our landscape, and they are referred to as an "unsung" component of British Columbia's forests (Centre for Applied Conservation Biology u.d.) This said, they occupy a significant proportion of the forested landscape. Pure stands of these species occupy 11% of the forested landscape and a further 24% of forest stands are mixtures of broadleaves and conifers (Comeau et al. 1996). Until the 1990's, annual harvests of broadleaves were very small, representing about 2% of the provincial harvest (Massie 1996), which is much smaller than their presence in the landscape might suggest. And to foresters of that time, broadleaves were considered a nuisance, subject to cutting or spraying because they threatened the dominance of market-favoured conifers.

Since about 1990, the picture has begun to change. The ecological role of broadleaves in the many provincial forest types is now widely acknowledged and their importance to Aboriginal culture and rural communities is receiving more attention (Royal Roads 2006) in forestry circles. The industrial harvest of broadleaves has increased and now stands at 3 million cubic metres, which represents about 5% of the provincial total. This is largely a result of advances in the manufacture of oriented strand board (OSB) products. There are several OSB plants in the Peace River country, but the actual annual harvest servicing this industry is still much less than the potential annual harvest (Massie et al. 1996). In silvicultural circles, improved understanding of the ecological role of the broadleaved species has modified attitudes about mechanical and chemical weeding treatments, but conifer management remains the dominant paradigm (Simard and Vyse 2006). In summary, broadleaves are no longer reviled, but are suffered. Like children in the Victorian era, they are expected to be seen but not

[1] See Appendix 1 for discussion on the use of the term "broadleaved" when applied to tree species in B.C. and why it is preferred to "deciduous" and "hardwood".

heard. Some have called broadleaves a "Cinderella" species, but if this is so, Prince Charming is taking his time!

The purpose of our report is to assess priorities for expansion of broadleaf genetic testing and improved seed or vegetative production. Investment in tree improvement work must be set in the broader context of ecological and economic conditions. Accordingly, our report sets out to describe the broadleaved species that occur in the Interior of BC, the current management of broadleaved and mixed broadleaf-conifer forest types, the potential for increasing their management and harvest, the status of biological and economic research on the species and their management, and existing genetic improvement work. We conclude with an assessment of the potential for further investments in genetic improvement.

Broadleaved species in the Interior of B.C.

In the Interior there are three dominant species of long term commercial interest: trembling aspen; paper birch; and *Populus balsamifera L.* with two sub-species of known as balsam poplar and black cottonwood.

The botanical terminology for these species has been subject to some debate, primarily because paper birch hybridises with other closely related native species, and the balsam poplar subspecies inter-grade and are often difficult to tell apart. Klinka et al. (2000) regard balsam poplar and black cottonwood as separate species, not subspecies, but in this report we will use the following terminology based on Douglas et al. (1998 and 2000):

- *Betula papyrifera* Marsh. var. *papyrifera (*var. *commuta* in SW BC), paper birch, shortened to birch in this report;
- *Populus tremuloides* Michx.*,* trembling aspen, shortened to aspen in this report;
- *Populus balsamifera* L.
    - ssp. *balsamifera* which is found mostly in NE BC; balsam poplar
    - ssp. *trichocarpa* (Torry and Gray) Brayshaw which is found throughout BC, black cottonwood, shortened to cottonwood in this report.

All three species occur throughout the Interior of B.C., except in the higher mountain ranges. Even there they can be found threading through the valley bottoms (see Klinka et al. (2000) for range maps).

There are an additional 10-20 woody broadleaved species that can attain tree size under favourable conditions. None of these have commercial importance for wood products at the present time, although they may be used for food and medicine or have high value for wildlife species. They include:

Betula occidentalis	water birch
Salix spp	willow
Prunus spp	pin and choke Cherry
Amelanchier alnifolia	saskatoon
Sorbus spp	western and sitka mountain ash
Alnus spp	green, sitka and mountain alder
Acer glabrum	Douglas maple
Rhamnus purshiana	cascara
Cornus stolonifera	red-osier dogwood
Corylus cornuta	hazlenut
Crataegus douglasii	black hawthorn

Historic use patterns

All of the major broadleaved species were widely used by First Nations groups throughout the B.C. Interior (Turner 1979). For example, birch bark had many uses including covering the frame of the Canadian canoe. Intricately worked baskets were made of birch bark for food storage. The wood of birch was used for implements of many kinds and the sap was used as a drink. One First Nations leader has spoken of the "$1000 birch tree", as a way of emphasising the many traditional uses for a species often treated as a weed in modern forest management (Royal Roads 2006). Large cottonwood trees were also used for dug-out canoes for travelling the large lakes and rivers of the Interior. And this species, with aspen, had numerous medicinal uses, in addition to serving as food and habitat for wildlifespecies with strong ties to the fur trade.

Since European settlement, commercial use of broadleaved species has been modest and is dwarfed by the use of the conifer species. For many years cottonwood was the only species to be exploited on any scale. It was cut in valley bottoms of the Coast and Interior to supply the Scott Paper (now Kruger Products) mill in New Westminster. In the 1990's, there was a brief flurry of interest in aspen with investments in a manufacturing plants to supply the Asian market with disposable chopsticks. This interest faded quickly, but was replaced by a much more substantial interest in the use of aspen for OSB paneling. Investments followed and there are now three large plants in the north east of the province using aspen and balsam poplar for OSB panels.

Existing and potential commercial ranges

Aspen, paper birch, balsam poplar and cottonwood grow to commercial size and stand volumes only within the moister ecological zones of the Interior and on sites with fresh to wet soil moisture and medium to rich soil nutrient regimes. They have very little or no production potential in the high elevation zones (Engelmann Spruce-Subalpine Fir; ESSF), the high latitude zone (Spruce-Willow-Birch; SWB) and the driest forested zone (Ponderosa Pine; PP), and very limited potential in the dry Interior Douglas-fir (IDF) zone, and the cold and dry Sub-Boreal Pine and Spruce (SBPS) and Montane Spruce (MS) zones (see Table 1). Their general distribution appears to be limited by summer precipitation, and various combinations of winter and summer temperatures.

Within the commercial ranges, the broadleaved species are susceptible to a variety of problems. Frost has been reported as having a limiting influence on birch establishment (Carlson et al. 2000) and may be responsible for the sharp upper elevation limit in the landscapes of the Interior. Birch is also susceptible to moisture deficits at establishment which results in premature leaf sensescence. It also seems susceptible to drought after 50 years of age, and prolonged dry conditions may be the trigger for "birch decline" that has been reported from the southern Interior in recent years (M. Cleary, pers. com.; V. Berger pers. com.). In eastern Canada, yellow birch (*Betula alleghaniensis*) decline has been correlated with unseasonal winter thaw-freeze events that cause cavitation in wood cells and interrupt water and nutrient transport, but similar observations have not been made in paper birch (Bourque et al. 2005). Bronze birch borer (*Agrilus anxius*) has been implicated in the decline phenomenon since it attacks overmature and weakened trees in the crown and then progresses down the tree (Peterson et al. 1997). The introduced birch leaf miners (*Fenusa pusilla; Profenusa thomsoni*) are two other common insects in the southern Interior that may also contribute to the birch tree decline. This problem is more severe in the southern than central Interior of the province (M. Carlson pers.com.), suggesting a strong climatic influence.

Cottonwood is also susceptible to water deficits. It is known to establish on upland sites but rarely reaches maturity there. Water stress does not seem to be a problem in stands located in valley bottoms. Moisture defict problems have not been reported for balsam poplar subspecies. Aspen is less susceptible to moisture deficits than either birch or the other poplars and also requires a lower level of nutrients for survival. It has been reported as suffering dieback throughout North America, but no single cause has been identified[2]. Multiple stressors, including forest tent caterpillar (*Malacosoma disstria* Hbn.), drought, and thaw-freeze, are

[2] noted in the SAF Forestry Source Newsletter June 2007 p20

thought responsible for dieback of aspen in Alberta, and there is concern that the severity of these stressors will increase with climate change (Hogg et al. 2002).

All of the broadleaved species have a wide variety of native insects and diseases that affect their growth and mortality. Even so, Klinka et al. (2000) regard the risk of widespread mortality due to insects and disease as low for birch, cottonwood and balsam poplar. Defoliating insects and foliar diseases are common to all four Interior broadleaves but the impact is thought to be relatively low. The bronze birch borer may represent a serious threat to birch in the southern Interior, particularly in combination with warmer and drier summers as well as the prescence of Armillaria root rot. For aspen, the risk is considered low for insects but moderate to high for pathogens (see Lewis 1996) because of butt and stem rots, stem cankers and leaf rust fungi. Stem cankers can be a serious problem throughout aspen's range. Cottonwood is at high risk for butt and stem rots and most trees on upland sites are infected by age 20.

The most common diseases affecting aspen, and other poplars, were summarised by Callan (1996), and threats to hybrid poplar on the Prairies have been summarised by van Oosten (2006). None of the many organisms on the list are considered likely to prevent successful establishment, but the risk from introduced pests has not been fully evaluated for the province. Callan (1996) described the threat to hybrid poplar plantations on the coast from a rapidly spreading, introduced leaf rust. One introduced insect, the poplar-willow borer, is associated with some loss of wood quality in cottonwood, but its economic impact is unknown because there are no major markets for solid wood. The introduction of gypsy moth (*Lymantria dispar*) from either the east of North America, or from Asia, would have a major impact on all broadleaved species (Peterson et al. 1997). Van Oosten (2006) considers that selection and propagation of resistant clones is a long term, cost effective strategy for mitigating damage caused by pests and diseases of hybrid poplar, and he recommends planting a variety of clones as a standard preventative practice. Fungicides and herbicides are also available for many of the identified disease and insect pests (van Oosten 2006) but these strategies would be effective only where intensive management is practiced.

Climate change is expected to have a major influence on the health of Canada's forested ecosystems in this century and changes in forest disturbance regimes and the distribution of forest types are expected. Projections of the future distribution of tree species have been made by Hamman and Wang (2006) and McKenney et al. (2007) using the climate envelope for species derived from the current distribution, and future climate forecasts from global models. They provide maps that suggest that the current wide distributions of the species of interest here, and thus their wide climatic envelopes, provide some degree of protection against climate change. However this conclusion does not take into account the possibility of changes in pest impacts or other damaging agents. All we can conclude at this juncture is that the effects of climate change on the present distribution of all tree species is highly uncertain.

Current Inventory data

The most recent provincial inventory data shows that there are 600 million cubic metres of broadleaved species in the province (Table 2). While this is small relative to the volume of conifers, the amount is still impressive. About 60% of the total volume is found in the Peace River and Fort Nelson Forest Districts east of the Rocky Mountains. Aspen is the most prevalent species by volume and area by a large margin, with more than twice the volume of the other two species groups combined.

West of the Rockies, the amount of broadleaf species generally declines from the north to the south and west. In the south, the Kamloops and Central Cariboo (Williams Lake) Districts have high volumes of all three species, while the Okanagan-Shuswap District has a relatively large volume of birch in the warm moist valleys around the lakes in the eastern part of the District. The 100 Mile District has a large amount of aspen on the Bonaparte Plateau.

The current volume estimate is about 2.7 times that provided by Massie et al. (1994). Part of the difference is attributable to the earlier, very low volume estimates in the Fort Nelson District, presumably because of inadequate inventory data. There were also large increases in volume estimates in almost all other Districts because of refinements in inventory methods or definitions of merchantable broadleaved timber.

The area of land containing broadleaved species is subject to considerable interpretation because much of the volume is found in mixed stands interspersed with conifers. However the distribution pattern reported by Massie et al. (1994), and shown in Appendix 2, is similar to the distribution shown in Table 2.

Current harvest levels and management

The harvest of broadleaved species in 2005-06 was 2.8 million cubic metres (BC Ministry of Forests and Range 2007), and was concentrated in the Fort Nelson, Fort St. John and Dawson Creek Timber Supply Areas (TSA). In all three areas, the broadleaf harvest is managed under a partitioned cut, which means that Licensees have separate conifer and broadleaf cuts and conifers cannot be substituted for broadleaves in the harvest operations. Although a broadleaved species breakdown is not given, the majority of the timber harvested is aspen and balsam poplar, which are used for the manufacture of OSB, pulp, and chips for export. Birch is also used for OSB but in small quantities. Elsewhere, birch is used as a raw material by a wide array of small scale businesses (Royal Roads 2006).

These businesses are found throughout the southern Interior but there is a notable concentration of them in the Quesnel area. The products that are typically produced include: furniture; cabinetry; flooring; lumber for window and door framing; veneer; OSB; and firewood.

Management for broadleaved species is at a very low level despite the production of several management handbooks (Simard and Vyse 1992, Peterson and Peterson 1992 and 1996, Peterson et al. 1997). The only widespread and deliberate management for broadleaves involves the natural regeneration of aspen following harvest of aspen-leading stands. Otherwise, the broadleaved species are tolerated at low levels and are generally targeted for removal in operations designed to achieve free-growing stands comprised of selected conifer species in the first 10 years following plantation establishment (Simard and Vyse 2006).

There is no commercial scale planting of any of the native broadleaved species in the Interior. Only birch is produced in commercial nurseries, but even then it is produced on a very small scale. Interior hybrid poplar plantations have been established on private land in the Vernon area in association with the City of Vernon to aid in land-based sewage effluent disposal (Carlson 1992). Some broadleaved species are used in road bank stabilisation and stream restoration activities.

Current commercial values

Because markets for broadleaved species are so weak across the province, the data on commercial values is very limited. Log market values from the Timber Pricing and Revenue Branch show that from 2003 to 2007, prices for “deciduous” logs ranged between $30 and $35 per cubic metre. Since current harvest and transportation costs range from $25-$35, revenue to the crown in the form of stumpage revenue is generally at the minimum possible amount of $0.50. By comparison, stumpage prices for conifer species over the same time period ranged from $10-35.

Although paper birch is not ascribed a specific commercial value for non-timber forest products, the mixed birch-conifer forests are the source of a lucrative, largely unregulated market for edible mushrooms in interir B.C. Many interior families rely on the fall mushroom harvest for a large portion of their annual income. The commercial harvesting of wild edible mushrooms, particularly chanterelles, pine mushrooms, boletes and morels in the mixed interior forests, is a growing multi-million-dollar industry in British Columbia (BC Ministry of Forests and Range 1995).

Potential for expansion in harvest of broadleaved species

Optimistic forecasts for increased utilization of Iinterior broadleaved species have been made for 80 years[3] and optimism still exists. Massie (1996) suggested that the potential level of harvest in BC could reach 6.4 million cubic metres by 2016,. In our view, such a rapid increase in broadleaf utilization is highly unlikely. A slow increase in utilization levels following the trend established over the last 15 years is more probable. The principal opportunity exists in the north eastern portion of the province. Here the current level of broadleaf utilization is substantial but well below the established and potential AAC levels (see Table 3).

Many efforts to accelerate utilization of broadleaves have also been made. In one of the latest efforts, the BC Wood Marketing agency reported that a birch grading and products guide for the US market had been published and that an aspen exposition had been held for the Japanese market (Downing 2005). They state that "from North America to Asia, there is growing interest in native western Canadian hardwoods such as birch and aspen", but this interest has not yet translated into an active market.

Some observers have suggested that global wood demand will lead to an increasing demand for BC wood products and thus perhaps broadleaved species. A recent assessment by the US National Commission on Science for Sustainable Forestry (2005) is less optimistic. The authors point to a relatively flat demand for wood on a global basis despite growing populations and incomes, and falling prices for wood products. They point to declining population growth in the developed world, greater efficiency of wood use, and expansion of forest plantations as contributing influences.

Two factors could change this assessment with respect to broadleaved species management in B.C.: the after-effects of the mountain pine beetle epidemic, and the widespread use of carbon credit trading.

1. Effect of the mountain pine beetle epidemic in the central and southern Interior

Initial salvage estimates for pine beetle-killed timber are thought to be optimistic, and there are forecasts of conifer timber shortfalls. Substantial reductions in the AAC are now forecast for Timber Supply Areas (TSA) from Smithers to Kamloops and Merritt over the next 10-15 years (BC Ministry of Forests and Range 2007c). Future projections for beetle infestations in pine forests that will mature over the next 50 years also bode poorly for future AAC levels (BC Ministry of Forests and Range 2006).Given that in some parts of the beetle-infested landscape, broadleaved species are the only green in a sea of red, their value is likely to rise.

---

[3] see quote from Garman (1929) in Peterson and Peterson (1996)

The most likely increase in utilization will be in the form of pulpwood as Interior mills seek to replace supplies of conifer chips. Scandinavia offers an example of such a shift (Puttonen 1996). Birch species form a substantial proportion of the growing stock in northern Sweden and Finland, but were underutilised until the 1970's. Since then, utilization has grown steadily, and now log prices for birch exceed those for conifer species. Management of birch is much more intensive than before, and deliberate management of birch mixtures with conifers is more common.

A similar shift in BC seems remote, although the pine beetle epidemic ought to re-focus reforestation programs to ensure that future stands have a mixed species composition, including much larger amounts of broadleaves. Martin et al. (2005) do not hold this view. In their Ministry of Forests and Range report on species composition in regenerating cutblocks within TSA's affected by mountain pine beetle, they recommend against any increase in broadleaf species composition above current low levels without detailed study in local areas. Ironically, they do not offer any detailed rationale for their recommendation. Simard and Vyse (2006) report a similar bias gainst broadleaves with respect to managing mixtures of conifers and broadleaves in the southern Interior. These attitudes are likely to continue as long as managers persist in thinking that the timber values of conifers will continue to be much higher than those of broadleaves into the distant future and that timber values should always trump ecological or non-traditional use values.

2. Carbon credit trading

The market in carbon credits could have a substantial impact on the future use of broadleaves in Canada. Maturing stands of aspen, for example, have been shown to be among the largest carbon sinks in Canadian forests (FluxNet Canada 2003), pointing to opportunities for broadleaf forest conservation and afforestation. Trading in carbon credits and carbon off-setting is already underway in North America (Rudell et al. 2007). Trading on the Chicago Climate Exchange is well established, and many airlines, including Air Canada and West Jet, have recently provided their customers with an opportunity to offset the carbon emission cost of their flights by purchasing carbon credits from a company planting seedlings in a subdivision near Port Coquitlam[4] . Recent developments in trading rules in California could lead to much greater investment in forest based carbon credits throughout the continent. Credits based on afforestation could, for example, lead to investments in hybrid poplar plantations in the Peace River, where there is considerable potential on former agricultural crop lands (Kabzems 2006); this is

[4] However there is considerable sceptism about the value of voluntary carbon offsetting. British students have posted a humourous video on UTube, in which they satirise the practice by comparing it to donating a fee to offset sins such as cheating on one's partner. The purchase of "indulgences" has a long history.

based on research carried out by the Saskatchewan Forest Centre. Forest management credits might also be available for the increase in biomass in mixed broadleaf-conifer stands compared to the biomass produced under standard management practices. This could encourage planting of paper birch, or aspen, in mixtures with conifers across most of the province.

.

Impediments to future broadleaf management

There are four main impediments to the greater use of broadleaved species in the Interior.

- Dispersed volumes of broadleaf species in the mixed species forests of the southern part of the Interior
- Low solid wood quality of stands because age of stands is high
- Tenure system
- Species selection and free growing policies

Dispersed volumes of broadleaf species in the southern part of the Interior.

In the southern Interior, volumes of broadleaved species are spatially dispersed either in mixed forests or along valley bottoms, and there has been no interest in major investment to increase utilization. Current utilization operations are small scale and scattered. However, this situation could change in the future awith maturity of second growth stands in which broadleaves are managed in mixture with conifers. Unfortunately, conifer-focused stand management efforts in the 1990's reduced the future volume of broadleaves to low levels in many accessible areas (Simard et al. 2001), and pushed back the time frame for future supplies.

Low solid wood quality

In the southern part of the Interior, the age of the broadleaved species is high relative to the preferred rotation age. The broadleave species grow quickly but lose quality after five decades or so because of increased disease and declining stem form. Stands with a mixture of broadleaved and conifer species are harvested at 80 years or older, and hence the quality of harvested broadleaved stems is often low. In these harvests the broadleaved species are frequently discarded in waste piles. This could change in future with a more rational approach to stand management.

Tenure system

Timber in B.C is harvested by private companies holding timber licenses granted under the Forest Act. The amount of timber harvested by a licensee in any given TSA is regulated by allocations which are in turn governed by the AAC approved for the TSA by the Chief Forester for the Province. Any volume removed from the forest by a licensee is counted as part of the cut allocated to their licence, regardless of value. Since no licensee is interested in harvesting and selling low value tree species when they can harvest higher value conifers, there is a tendency to leave the low value species (such as hemlock and broadleaves) in the forest. Small businesses producing broadleaves report difficulties in obtaining a sufficient and regular supply (Royal Roads 2006 and confirmed by our investigations) because the prices they are willing to pay are well below the prices quoted by major licensees. They frequently express frustration with this state of affairs. Their main source of supply is from private timber and woodlots where the owners have a strong interest in maximising log sales.

The recent reallocation of timber from major licensees to BC Timber Sales could have some effect on the supply of broadleaved trees to small businesses. However, the volume of timber removed is still charged against the overall cut. Where partitioned cuts for broadleaf species have been calculated, as for example in the Peace River country, and in the Kamloops TSA, this difficulty associated with the tenure system is removed.

Species selection and free growing policies

In the northern temperate and boreal forests of western Canada, broadleaves are commonly removed from plantations in efforts to increase conifer production (Lieffers et al. 1996; Comeau et al. 2000; Wagner et al. 2001, 2005). This practice is based on the assumptions that broadleaves compete intensively with conifers for resources, their facilitative effects are of low importance to ecosystem function, intensive weeding will result in greater conifer productivity and their economic value is low. Weeding has been encouraged by the free-growing policies of several Canadian provinces (Brand and Weetman 1986; Comeau et al. 2000; Lieffers et al. 2002). These policies regulate acceptable levels of competition from broadleaf trees and other vegetation As an example, the typical management pathway for achieving free-growing, high-yield conifer stands in BC interior forests over the last 20 years has aimed at increasing conifer survival and growth rates through the reduction of competition from neighbouring vegetation.

As part of the growing acceptance of broadleaves and their ecological values, free-growing standards have been modified in B.C. (British Columbia Ministry of Forests 2000) to include broadleaved trees as a component of acceptable stands, but *only* where the effect on conifer crop tree growth is minimal. This condition is rarely encountered because aspen, birch and cottonwood grow more rapidly in the first 10 to 20 years than most conifers. Thus, many conifer plantations in the interior forests do not meet free-growing requirements without a brushing treatment to remove the broadleaf trees. For example, Simard et al. (2001) found that all forest types in the Interior Cedar Hemlock zone were comprised of a mixture of species prior to the mid-1990's, but since then, the current combined program of planting, brushing and spacing has converted 39% of new forests to types comprised predominantly of Douglas-fir or lodgepole pine. This management pathway is expensive based on international comparisons (Simard and Vyse 1994), and by 2005, costs were up to $3000 per hectare where repeated manual treatments were necessary.

Advantages of managing for broadleaves

The ecological and economic value of broadleaved trees to forest ecosystems has received increasing attention in Europe and North America (Swanson et al. 1997; Löfman and Kouki 2001; Lautenschlager 2000; Comeau et al. 2005). The benefits of including some proportion of non-coniferous species in future managed forest is widely recognised across western North America. Early reports concentrated on the value of these species to wildlife (Enns et al. 1993) and the need to retain minor amounts of these species in future forests, particularly in riparian zones. A more broadly based approach (Centre for Applied Conservation Biology u.d.) emphasised the role of broadleaved trees in nutrient cycling, plant succession, food and cover and nesting sites for animals, providing visual values and broadening the diversity of structures and organisms in forests. With more research, the broader contribution of broadleaved species to biodiversity, forest health and ecosystem functioning has been recognized (e.g. Hagar 2007, Lindenmayer and Franklin 2002, Aitken et al. 2002, Simard et al. 2005) and the need for a multi-scale approach to planning species retention along multiple management pathways has been proposed (Simard and Vyse 2006; see Appendix 3).

Free-growing policies, such as those in effect in BC, have focused on early broadleaf competition for site resources (Brand and Weetman 1986; Lieffers et al. 2002), ignoring the possibility that broadleaves can have facilitative effects on conifer regeneration, or that competitive effects can vary over time and space. Previously, for example, broadleaves have been shown to help limit spread of root disease among conifers (Morrison et al. 1988; Gerlach et al. 1997), reduce the risk of conifer attack by weevils and spruce budworm (Taylor et al. 1996; McIntosh et al. 1996), protect understory conifers against frost (Andersson 1985; Pritchard and Comeau 2004), provide habitat for ungulates, small mammals and birds (Peterson et al. 1997; Aitken et al. 2002), and contribute to soil productivity through nutrient rich litter inputs (Brockley and Sanborn 2003). In keeping with this last point, total yield (conifer plus broadleaf) in mixed forests has sometimes been higher than in pure coniferous forests because of niche separation (Kenk 1992; Mielikainen 1996; Man and Lieffers 1999; Frivold and Kolström 1999; Valkonen and Valsta 2001). Even though birch and aspen can compete with conifers early in stand development, they self-thin, decline and die relatively quickly because they are pioneer species (Klinka et al. 2000; Comeau et al. 2003; Simard and Sachs 2004Kabzems and Garcia 2004). Hence, their competitive effects on conifers are relatively short-lived over the rotation of a mixed stand (Frivold and Frank 2002; Simard et al. 2004a).

Extensive application of intensive conifer management has raised concerns about the diversity, health and resilience of the western North American forests in general (Lieffers et al. 2002; Woods et al. 2005). In addition to their lower structural diversity (Haeussler and Bergeron 2004), these conifer plantations have been subject to widespread insect and disease damage, such as from Dothistroma needle blight (*Dothistroma septosporum* (Dorog.) Morelet) and *Armillaria ostoyae* root disease (Woods et al. 2005; Cruickshank et al. 1997). This kind of damage, along with mortality caused by drought and fire, is expected to increase in southern Interior B.C. with climate change (Hamman and Wang 2006; Hansen et al. 2005). Not only is this management pathway expensive, but it may be placing our forests at an elevated risk for future problems in the face of climate change.

Simard and Vyse (2006) have elaborated on the biological risks and considerable uncertainty associated with the expected outcomes of current management practices aimed at producing coniferous sawlogs in the mixed forest types in B.C. Concerns about conifer regimes have been expressed by environmental groups, and the province seems likely to experience pressures for a more natural forestry (Hammond 1991), including mixed conifer and broadleaf management, to meet visual, biodiversity and climate change objectives, following trends in Germany and Scandinavia (Kenk 1992; Puttonen 1996) and elsewhere in Canada (Comeau et al. 2005). Less prominent are concerns about the economic wisdom of a conifer strategy. Broadleaves were once regarded as low value species in Europe, in much in the same way that they are regarded in the Interior B.C. today. In Finland, prices for birch products rose rapidly in the 1980s (Puttonen 1996). Haight (1993) demonstrated the importance of stochastic price trends in his analysis of the economics of Douglas-fir and red alder management in the Pacific North West. When investments have a long gestation period, and prices are highly uncertain, portfolio diversification is usually recommended.

Simard and Vyse (2006) have proposed an alternative management approach to incorporate the manay advantages of managing for broadleaves. We suggested a "mixtures" program in which there would be three main pathways, to be applied in different proportions following harvesting across the landscape (see Appendix 3). In doing so we argued that the management program would be less costly in total, provide a greater range of forest products, provide a hedge against uncertainty in future wood product markets, and provide opportunities for the development of non-traditional forest products, particularly those associated with broadleaved species, which are either limited or not available under the current management approach. The program uses an ecological approach to management that integrates facilitative and competitive interactions in forest communities, and accounts for trade-offs between survival and growth that can result from manipulation of broadleaf trees. We further suggested that a mixed conifer-broadleaf forest would provide a greater buffering capacity than single species forests against the stresses that climate change will impose. In addition, because mixed forests serve as habitat for a rich array of plant and animal species, they should be conserved as much as possible along valley bottoms to provide connective corridors for northward migration of species with climate change (Paerson and Dawson 2005). Inclusion of broadleaves in critical patterns on the landscape for mitigating spread of wildfires has been studied for inclusion in landscape plans elsewhere in Canada (Parisien and Junor 2006). However, we are not optimistic that our proposal will be accepted by the Ministry of Forests and Range in the near future.

Scientific background for broadleaf management

We evaluated the scientific background for future broadleaved species management and the existing information on gene conservation and tree improvement. We surveyed the scientific literature dealing with the three species of major importance in the Interior published since the management handbooks produced in the mid 1990's (Simard and Vyse 1992, Peterson et al. 1997, Peterson and Peterson 1996). We identified 723 citations, including some important papers that were not cited in the handbooks. Most citations were published after 1993. The reference list is shown in Appendix 4. The major topics covered in the literature are summarised in Table 4.

Aspen was the subject of 60% of the studies located. Nearly 20% dealt with cottonwood, hybrid aspen and hybrid poplar. Birch was the focus of 10% of the studies. However, this relative neglect of birch is compensated to some degree by a large recent literature on two European birch species (*Betula pendula* and *B. pubescens*) which share many features with paper birch. Balsam poplar is the least studied of the species of concern. It is generally ignored unless it is a component of general *Populus* studies.

The subject of the studies cited in the bibliography ranges widely from studies in general biology and ecology to management. There are relatively few products oriented papers but this may be a function of the bibliographic search. The quality of the work ranges from the *Populus* monograph issued by NRC Press (Stettler et al. 1996.) to very narrowly focussed papers dealing with the genetic structure of *Populus* species.

The bibliography includes a large number of investigations dealing with possible climate change effects on the broadleaved species. There are numerous physiological studies of responses of aspen and other poplars to increased CO^2 and O_3 and a few dealing with measuring carbon flux in regenerating stands of aspen. But few if any of the papers deal with climate change interactions with tree species, existing or potential damaging insects and diseases, or tests of practical measures that might support ecologically-sound forestry to conserve native species mixtures.

Silvicultural tests of broadleaf management

A wide variety of tests of broadleaf management have been initiated in the Interior since 1990. The Experimental Project lists available from the Provincial Forest Research Branch show that about 70 trials have been conducted ranging from tests of the nitrogen contribution of alder shrubs to conifer plantations to thinning trials in pure broadleaf stands. A sample of the projects is shown in Table 5. The list demonstrates that there is a strong and growing base of information on which future management of broadleaved and mixed broadleaf-conifer stands can be based. However, none of the existing trials provide information on the adaptability of the species under future climates.

Gene conservation and tree improvement programs

Small programs in all species except balsam poplar have been started in B.C. Gene conservation *In situ* gene conservation has been evaluated for birch by UBC Centre for Forest Gene Conservation[5] .The centre notes that populations of birch have been protected in many parts of the province but that those in the SBS and IDF zones are under-represented by the current distribution of protected areas. We suspect that this statement is also true for aspen and the sub species of *P. balsamifera*, based on their similar geographic distribution.

Ex situ gene conservation of the Interior broadleaved species is limited to birch and some cottonwood work. The Gene Conservation Centre does not report work for either aspen or *P. balsamifera*.

A low level of genetic testing is underway for three of the four Interior broadleaved species - birch, aspen and cottonwood – but not for balsam poplar. There is a small-scale but active hybrid poplar program.

---

[5] see http://genetics.forestry.ubc.ca/cfgc/proj_cataloguing/

1. Birch

A small genecology program has been underway since the mid 90's. The first trial initiated in 1996 is testing 18 seed sources on 4 sites, a second trial established in 1998 is testing 195 wind pollinated families trial and a third, more elaborate, genecology trial established in 2001 includes selections from a provincial latitudinal and elevation grid. The family trial was the source of 36 clones for the first paper birch seed orchards to be established at Kalamalka and Skimikin this year. Substantial productivity gains are expected as a result of the selection. The Lee Creek and Skeena River provenances show considerable promise in the later trial.

Selected strains of *Betula pendula* (silver birch) from the Finnish birch breeding program have been grown at Skimikin for nearly twenty years. These trees have reached 20 m in height after 15 years but are slender, with diameters of 15-20 cm. Silver birch has not been used in plantation trials in BC. Birch decline has been observed in the silver birch trial at Skimikin.

2. Aspen

Very little genetic work has been carried out on aspen. Material from about 50 sources was collected for a genecology trial about 10 years ago (Ministry of Forests and Range 2007d) but the field trials have not been implemented.

Hybrid aspen (P. tremula x P. tremuloides) material from the now discontinued breeding program in the Lake States of the U.S. was established on sites at Slimikin seed orchard, Prince George and Fort Nelson. Some work on hybrid aspen propagation is underway at SFU.

3. Cottonwood

Genecological work on the cottonwood/balsam poplar species complex began three years ago. Material from around the province is being tested at three sites: Harrison Lake, Prince George and Terrace.

4. Hybrid poplar

Work on testing poplar hybrid material in the Interior began at Kalamalka Research Station in 1984, supplied initially by the poplar breeding program at the University of Washington. Field tests of large numbers of hybrid clones were made in 1988, 1989 and 1993 (Carlson 1996). Out-plantings have been made at numerous locations in the Interior, and good growth has been observed but only under intensive cultivation conditions. The hybrid material has been used on an operational basis as part of the City of Vernon's successful wastewater treatment program (Carlson 1992). Further expansion of this program to other municipalities seems unlikely in the near future.

More recent work has involved testing of 50 clones from hybrids of central BC cottonwood selections and eastern cottonwood (*P. deltoides*) of northern origin. Promising results have been reported from a trial of hybrid poplar in the Creston valley where gross increments of 35 m3/ha over 10 years have been recorded (M. Carlson pers.com).

Recommendations for future genetic research

We do not recommend a large expansion of genetic improvement research in Interior broadleaved species at this time. While a slow expansion of broadleaved species utilization in the north has taken place over the last twenty years and seems likely to continue, management intensity is low. In the south, mixed species management is also growing and could accelerate rapidly if policy constraints were removed. However, the renewal of broadleaved species throughout the Interior is based on natural regeneration and opportunities for using improved stock in renewal programs seem limited over the next decade or more. More likely is the emergence of relatively small "niche" opportunities such as the creation of biofuel plantations on agricultural land in the Peace Region and the use of paper birch as a treatment in the treatment of root disease areas. However, we caution that some of the assumptions and assertions we have made in our assessment may not hold as a result of the rapid rate of change in some parts of the BC forestry world. The current economic crisis in the forest industry and uncertainty about climate change effects are but two examples. Thus, we suggest that the question of further expansion of effort should be revisited within five years.

We do advocate expansion of the existing work on the genecology of broadleaved species. Given the uncertain future, we expect that a modest investment in protecting gene resources and gaining a greater understanding of our ecologically important but neglected broadleaved species will prove wise. This improved protection and understanding will be critical if the Ministry of Forests and Range undertakes programs to facilitate tree species migration to cope with climate change, whether it involves active movement of species or simply conservation of species corridors for natural migration.

Our specific recommendations are as follows:

1. Continue genecological investigations of birch and cottonwood subspecies;
2. Initiate genecological investigations in aspen and balsam poplar;
3. Implement a systematic gene conservation program for all interior broadleaved species;
4. Initiate study of the establishment of fast growing varieties and hybrids of aspen, cottonwood, balsam poplar and willow on cleared land for bioenergy and carbon capture crops, in the Peace River region *in cooperation with work already underway in Alberta and Saskatchewan;.*
5. Continue current moderate level of genetic improvement work in birch with the aim of establishing a network of trial plantations of birch, and birch mixed with improved conifer material, on suitable sites in the Interior;
6. Establish "smart mixture" trials where a range of genetically improved mixtures are tested on an operational scale across a latitudinal gradient for future facilitated migration programs with climate change;
7. Maintain cottonwood, silver birch and hybrid aspen genetic improvement work at current low levels;
8. Investigate the potential of using improved birch in conjunction with *Armillaria* management efforts in the southern Interior;
9. Initiate facilitated migration studies by planting broadleaved species genotypes outside of their current climatic envelope;
10. Strengthen existing cooperation of genetic specialists in research programs with tree physiologists, ecologists, silviculturalists and forest insect and disease specialists with the aim of establishing a strong scientific basis for management of broadleaved species in pure and mixed stands.

References

Aitken, K.E.H., Wiebe, K.L., and Martin, K. 2002. Nest-site re-use patterns for a cavity-nesting bird community in interior British Columbia. The Auk **119**: 391-402.

Andersson, S. 1985. Treatment of young mixed stands with birch and conifers. *In* Broadleaves in boreal silviculture-an obstacle or an asset? *Edited by* B. Hagglund and G. Peterson. Swedish Univ. Agr. Sci. Dept. Silv. Umeå, Sweden. pp 127-162.

Bourque, C.P.-A., Cox, R.M., Allen, D.J., Arp, P.A., and Meng, F.-R. 2005. Spatial extent of winter thaw events in eastern North America: historical weather records in relation to yellow birch decline. Global Change Biology **11**: 1477-1492.

Brand, D.G., and Weetman, G.F. 1986. Standards for regeneration establishment in Canada: a case study for Douglas-fir. For. Chron. **62**: 84-90.

Brayshaw, T.C. 1996. Trees and shrubs of British Columbia. Royal British Columbia Museum Handbook. UBC Press. 374p.

British Columbia Ministry of Forests. 1995. Botanical Forest Products in British Columbia – An Overview. For. Prac. Br., B.C. Ministry of Forests, Victoria, B.C.

British Columbia Ministry of Forests. 2000. Establishment to free growing guidebook. Kamloops Forest Region. Rev. ed. Version 2.2, For. Prac. Br., B.C. Ministry of Forests, Victoria, B.C., Forest Practices Code of British Columbia Guidebook.

British Columbia Ministry of Forests and Range 2007a. Annual Report for 2005-06. Accessed on line August 2007.

British Columbia Ministry of Forests and Range. 2007b. Timber supply analysis reports for Fort Nelson, Fort St. John and Dawson Creek. Accessed on line August 2007.

British Columbia Ministry of Forests and Range. 2007c. Timber Supply and the Mountain Pine Beetle Infestation in British Columbia – 2007 Update Forest Analysis Branch, Victoria, B.C.

British Columbia Ministry of Forests and Range. 2007d. Tree Improvement Branch Seed Planning Unit #48 Commercial Broadleaves-Interior. Accessed on line at – http://www.for.gov.bc.ca/hti/speciesplan/index.htm

Brockley, R.P., and Sanborn, P. 2003. Effects of Sitka alder on the growth and foliar nutrition of young lodgepole pine in the central interior of British Columbia. Can. J. For. Res. **33**: 1761-1771.

Callan, B.E. 1998. Diseases of *Populus* in British Columbia: a diagnostic manual. Nat. Resour, Can., Can. For. Serv., Victoria, B.C.

Carlson, M. R. 1992. Municipal effluent irrigation of fast-growing hybrid poplar plantations near Vernon, B.C. For. Chron. **68**: 206-208.

Carlson, M.R. 1996. Evaluation and testing of hybrid poplars in British Columbia. In P.G. Comeau et al. *eds*. Ecology and management of B.C. Hardwoods. B.C. Ministry of Forests, Victoria. FRDA Rep. No. 255. p 113-114.

Carlson, M. R. and V. Berger. 1998. Solid wood product opportunities from short rotation hybrid poplar trees. Victoria, B.C. Forest Renewal B.C. Research Project TO97203. 90p.

Carlson. M.R., V. Berger and C.D.B. Hawkins. 2000. Seed source testing of paper birch in British Columbia. J. Sustain. For. **10**:25-34.

Centre for Applied Conservation Biology. ud. Broadleaved trees: unsung component of British Columbia's forests. Univeristy of B.C. Vancouver, B.C. np.

Comeau, P. G., K. Thomas, and J. Boateng. Eds. 1996. Silviculture of Boreal and Temperate Broadleaved-Conifer Mixtures. Workshop Proceedings, 28 February and 1 March 1995, Richmond, B.C. British Columbia Ministry of Forests, Victoria. B.C. Land Manage. Handb. 36. pp.1-7

Comeau, P.G., Harper, G.J., Blache, M.E., Boateng, J.O., and Thomas, K.D. (editors). 1996. Ecology and management of B.C. Hardwoods. B.C. Ministry of Forests, Victoria. FRDA Rep. No. 255.

Comeau, P.G., Gendron, F., and Letchford, T. 1998. A comparison of several methods for estimating light under a paper birch mixedwood stand. Can. J. For. Res. **28**: 1843-1850.

Comeau, P.G., Biring, B.S., and Harper, G.J. 2000. Conifer responses to brushing treatments: a summary of British Columbia data. B.C. Ministry of Forests, Victoria, B.C., Extension Note 41.

Comeau, P.G., Wang J.R., and Letchford, T. 2003. Influences of paper birch competition on growth of understory white spruce and subalpine fir following spacing. Can. J. For. Res. **33**: 1962-1973.

Comeau, P.G., Kabzems, R., McClarnon, J., and Heineman, J.L. 2005. Implications of selected approaches for regenerating and managing western boreal mixedwood. For. Chron. **81**:559-574.

Cruickshank, M.G., Morrison, D.J., and Punja, Z.K. 1997. Incidence of *Armillaria* species in precommercial thinning stumps and spread of Armillaria ostoyae to adjacent Douglas-fir trees. Can. J. For. Res. **27**: 481-490.

Douglas, G.W., G.B Straley, D. Meidinger and J. Pojar. 1998. Illustrated Flora of British Columbia. Volume 2 (Basaminaceae through Cuscutaceaea). British Columbia Ministry of Environment Lands and Parks and Ministry of Forests. 401p.

Douglas, G.W., D. Meidinger and J. Pojar. 2000. Illustrated Flora of British Columbia. Volume 5 (Salicaceae through Zygophyllaceae). British Columbia Ministry of Environment Lands and Parks and Ministry of Forests. 389p.

Downing, B. 2005. Growing interest in BC Hardwoods. BC Wood News. Vol 3 #31. Accessed on line August 2007.

Drever, C.R., and Lertzman, K.P. 2001. Light-growth responses of coastal Douglas-fir and western redcedar saplings under different regimes of soil moisture and nutrients. Can. J. For. Res. **31**: 2124-2133.

Enns, K.A., E.B. Peterson and D. McLennan. 1993. Impacts of hardwood management on British Columbia wildlife: problem analysis. For. Can and Ministry of Forests. FRDA Report 208.

Frivold, L.H., and Frank, J. 2002. Growth of mixed birch-coniferous stands in relation to pure coniferous stands at similar sites in south-eastern Norway. Scand. J. For. Res. **17**: 139-149.

Frivold, L.H., and Kolström, T., 1999. Yield and treatment of mixed stands of boreal tree species in Fennoscandia. *In* Management of Mixed-species Forest: Silviculture and Economics. *Edited by* A.F. Olsthoorn, F.M. Bartelink, J.J. Gardiner, H. Pretzsch, H.J. Hekhuis, and A. Franc. IBN-DLO, Wageningen. ISBN 90-76095-08-6, pp. 37-45.

Fluxnet-Canada. 2004. Annual progress report. Fluxnet-Canada Network Management Office, Faculté de Foresterie et de Géomatique
Université Laval, Québec. 210p.

Gerlach, J.P., Reich, P.B., Puettmann, K., and Baker, T. 1997. Species, diversity, and density affect tree seedling mortality from *Armillaria* root rot. Can. J. For. Res. **27**: 1509-1512.

Hagar, J.C. 2007. Wildlife species associated with non-coniferous vegetation in Pacific Northwest conifer forests: A review. For.Ecol.Manage. **246**:108-122/

Haight, R.G. 1993. The economics of Douglas-fir and red alder management with stochastic price trends. Can. J. For. Res. **23**: 1695-1703.

Hamann, A., and Wang, T. 2006. Effects of climate and climate change on ecosystem and tree species distribution in British Columbia. Ecology **87**:2773-2786.

Hammond, H. 1991. Seeing the forest among the trees: the case for wholistic forest use. Polestar Press Ltd. Vancouver, B.C.

Hansen, J., Nazarenko, L., Ruedy, R., Sato, M., Willis, J., Del Genio, A., Koch, D., Lacis, A., Lo, K., Menon, S., Novakov, T., Perlwitz, J., Russel, G., Schmidt, G.A., and Tausnev, N. 2005. Earth's energy imbalance: confirmations and implications. Science 28 April 2005; 10-1126/science.1110252.

Kabzems, R., and Garcia, O. 2004. Structure and dynamics of trembling aspen – white spruce mixed stands near Fort Nelson, B.C. Can. J. For. Res. **34**: 384-395.

Kabzems, R. 2006. Hybrid Poplar Potential in the Peace Forest District. Ministry of Forests and Range, Northern Interior Region. Internal report. 5p.

Kenk, G.K. 1992. Silviculture of mixed species stands in Germany. *In* The ecology of mixed species stands of trees. *Edited by* M.G.R. Cannell, D.C. Malcom and P.A. Robertson. Blackwell Scientific Publ. Br. Ecol. Soc. **11**: 53-63.

Klinka, K, Worrall, J., Skoda, L., and Varga, P. 2000. The distribution and synopsis of ecological and silvical characteristics of tree species of British Columbia's forests. Canadian Cartographics Ltd., Vancouver. 180p.

Lautenschlager, R.A. 2000. Can intensive silviculture contribute to sustainable forest management in northern ecosystems? For. Chron. **76**: 283-295.

Lewis, K.J. 1996. Aspen decay and wood utilization. In P.G. Comeau et al. *eds*. Ecology and management of B.C. Hardwoods. B.C. Ministry of Forests, Victoria. FRDA Rep. No. 255. p 65-74.

Lieffers, V.J., Macmillan, R.B., MacPherson, D., Branter, K., and Stewart, J.D. 1996. Semi-natural and intensive silvicultural systems for the boreal mixedwood forest. For. Chron. **72**: 286-292.

Lieffers, V.J., Pinno, B.D., and Stadt, K.J. 2002. Light dynamics and free-to-grow standards in aspen-dominated mixedwood forests. For. Chron. **78**: 137-145.

Lindenmayer, D.B and J.F.Franklin. 2002. Conserving forest biodiversity: a comprehensive multi-scaled approach. Washington, D.C. Island Press.

Löfman, S., and Kouki, J. 2001. Fifty years of landscape transformation in managed forests of southern Finland. Scand. J. For. Res. **16**: 44-53.

Lortie, C.J., and Callaway, R.M. 2006. Re-analysis of meta-analysis: support for the stress-gradient hypothesis. J. Ecology **94**: 7-16.

McIntosh, R.L., McLean, J.A., Alfaro, R.I., and Kiss, G.K. 1996. Dispersal of *Pissodes strobi* in putatively resistant white spruce in B.C. For. Chron. **72**: 381-387.

McKenney, D.W., J.H.Pedlar, K. Lawrence, K. Campbell and M. F. Hutchinson. 2007. Potential impacts of climate change on the distribution of North American trees. Bioscience. **57**:939-948.

Maestre, F.T., Valladares, F., and Reynolds, J.F. 2005. Is the change of plant-plant interactions with abiotic stress predictable? A meta-analysis of field results in arid environments. J. Ecology **93**: 748-757.

Martin, P., B. Barber, C. Delong, D. Meidinger and M. Pelchat. 2005. Management of species composition in cutblocks in beetle impacted TSA's. Ministry of Forests and Range, Forest Practices Branch. 120p. Accessed on line October 2007. http://www.for.gov.bc.ca/hfp/fft/committees/sdag/reports/SpeciesManagement-All-Final-print.pdf

Man, R., and V.J.Lieffers 1999. Are mixtures of aspen and white spruce more productive than single species stands? For. Chron. **75**: 505-513.

Massie, M.R.C., E.B. Peterson, N.M.Peterson and K.A. Enns. 1994. An assessment of the strategic importance of the hardwood resource in British Columbia. B.C. Ministry of Forests and Forestry Canada, Victoria, B.C. FRDA Report 221. 206p.

Massie M.R.C. 1996. Harwood utilization and supply. In P.G. Comeau et al. *eds*. Ecology and management of B.C. Hardwoods. B.C. Ministry of Forests, Victoria. FRDA Rep. No. 255. p 1-7.

Mielikainen, K. 1996. Approaches to managing birch dominated mixed stands in Finland. *In* Silviculture of Temperate and Boreal Broadleaved-Conifer Species: Proceedings of a Workshop held Feb. 28-March 1, 1995, Richmond, B.C. *Edited by* P.G. Comeau and K.D. Thomas. B.C. Ministry of Forests, Victoria, B.C. Land Manage. Handb. 36:122-125.

Morrison, D.J., G.W. Wallis and L.C.Weir. 1988. Control of *Armillaria* and *Phellinus* root diseases: 20 year results from the Skimikin stump removal experiment. Can. For. Serv. Pac. For. Centre, Victoria, B.C. Info. Rept. BC-X-302

North House Folk School. 2007. Celebrating birch: the lore, art and craft of an ancient tree. Fox Chapel Publishing, East Petersburg, PA, USA. 192 p.

Paerson R.G., Dawson T.P. 2005. Long distance plant dispersal and habitat fragmentation : identifying conservation targets for spatial landscape planning under climate change. Biological Conservation **123**: 389-401.

Parisien M-A. and D. Junor 2006. The relationship between burn probability and fuel type dominance in the boreal mixedwood of western Canada. Prince Albert Model Forest Short report. Accessed on line October 2007 at http://mfiqlx.sasktelwebhosting.com/pubs/PAMF_short_report_March_2006.pdf

Peterson. E. B. and N. M. Peterson 1992. Ecology management and use of aspen and balsam poplar in the Prairie Provinces. Edmonton, Canadian Forest Service, Northern Forestry Station, Special report #1.

Peterson, E. B and N. M. Peterson 1996 Ecology and silviculture of trembling aspen. *In* Ecology and management of B.C. Hardwoods. Eds. P.G. Comeau, G.J. Harper, M.E. Blache, J.O. Boateng and K.D. Thomas. B.C. Min. of For. FRDA Report # 255

Peterson, E.B., Peterson, N.M., Simard, S.W., and Wang, J.R., 1997. Paper birch managers' handbook for British Columbia. Forestry Canada and B.C. Ministry of Forests, Victoria, B.C. FRDA Rep. 271.

Pritchard, J.M., and Comeau, P.G. 2004. Effects of opening size and stand characteristics on light transmittance and temperature under young trembling aspen stands. For. Ecol. Manage. **200**: 119-128.

Puttonen, P. 1996. Birch management in Finland. *In* Ecology and management of B.C. Hardwoods. *Edited by* P.G. Comeau, G.J. Harper, M.E. Blache, J.O. Boateng and K.D. Thomas. B.C. Min. of For. FRDA Report # 255:177-187

Royal Roads 2006. Market and Product Development for Birch Timber and Non-Timber Products: Current Status and Potential in British Columbia. Victoria, BC, Royal Roads University, The Centre for Non-Timber Resources. Report prepared for Forest Innovation Investment. Available at http://www.royalroads.ca. 20p.

Rudell, S., R. Sampson, M.Smith, R. Giffen, J. Cathcart, J. Hagan, D. Sosland, J, Godbee, J. Heisenbuttle, S.Lovett, J. Helms, W. Price and R. Simpson. 2007. The role for sustainably managed forests in climate change mitigation. J. For. **105**:314-319.

Simard, S.W., and Sachs, D.L. 2004. Assessment of interspecific competition using relative height and distance indices in an age sequence of seral interior cedar-hemlock forest in British Columbia. Can. J. For. Res. **34**: 1228-1240.

Simard, S.W. and Vyse, A. 1992. Ecology and management of paper birch and black cottonwood in southern British Columbia. B.C. Min.For. FRDA Report 75.

Simard, S.W., and Vyse, A. 1994. Paper birch: weed or crop tree in the interior cedar-hemlock forests of south British Columbia. *In* Interior Cedar-Hemlock-White-Pine Forests: Ecology and Management. *Edited by* D.M. Baumgartner, J.E. Lotan, and J.R. Tonn. Wash. State, Univ., Coop. Exten., Pullman, Wash., pp. 309-316.

Simard, S. and Vyse, A. 2006. Trade-offs between competition and facilitation: a case study of vegetation management in the interior cedar-hemlock forests of southern British Columbia. Can. J. For. Res. **36**:2486-2496.

Simard, S.W., Heineman, J.L., Mather, W.J., Sachs, D.L., and Vyse, A. 2001. Effects of operational brushing on conifers and plant communities in the southern interior of British Columbia: results from PROBE 1991-2000 PROTOCOL for operational brushing evaluations. Research Branch, B.C. Ministry of Forests, Victoria, B.C., Land Manage. Handb. No. 48.

Simard, S.W., Sachs, D.L., Vyse, A., and Blevins, L.L. 2004a. Paper birch competitive effects vary with conifer tree species and stand age in interior British Columbia forests: implications for reforestation policy and practice. For. Ecol. Manage. **198**: 55-74.

Stettler, R.F., Bradshaw, H.D., Jr., Heilman, P.E. and Hinckley, T.M. (eds). 1996. Biology of *Populus* and its implications for management and conservation. NRC Research Press, Ottawa, Ont.

Swanson, F.J., Jones, J.A., and Grant, G.E. 1997. The physical environment as a basis for managing ecosystems. *In* Creating a forestry for the 21st century: the science of ecosystem management. *Edited by* K.A. Kohm and J.F. Franklin. Island Press, Washington, pp. 229-238.

Taylor, S.P., Alfaro, R.I., DeLong, C., and Rankin, L. 1994. Effects of overstory shading on white pine weevil damage to interior white spruce. *In:* The white pine weevil: biology, damage and management. Proc. Symp., January 19-21, 1994, Richmond, B.C. *Edited by:* R.I. Alfaro, G. Kiss, and R.G. Fraser. Forestry Canada., Victoria, B.C., FRDA Report 226. pp. 254-261.

Turner, N. J. 1979. Plants in British Columbia Indian technology. B.C. Provincial Museum Handbook no. 38. BC Provincial Museum, Victoria, B.C. 304 p.

U.S. National Commission on Science for Sustainable Forestry 2005. Global markets forum. Summary report of the National Commission on Science for Susainable Forestry. NCSSF Project C9. Washington, D.C. 20p.

Valkonen, S., and Valsta, L. 2001. Productivity and economics of mixed two-storied spruce and birch stands in Southern Finland simulated with empirical models. For. Ecol. Manage. **140**: 133-149.

Van Oosten, C. 2006. Hybrid poplar crop manual for the Prairie Provinces. 2006. Accessed August 2007 at http://www.saskforestcentre.ca/uploaded/HybridPoplarManual.pdf

Wagner, R.G., Bell, F.W., and Campbell, R.A. 2001. Vegetation management. *In* Regenerating the Canadian Forests: Principles and Practice for Ontario. *Edited by* R.G. Wagner and S.J. Colombo. Fitzhenry and Whiteside, Markham, Ontario, pp. 431-457.

Wagner, R.G., Little, K.M., Richardson, B., and McNabb, K. 2005. The role of vegetation management for enhancing productivity of the world's forests. Forestry **79**: 57-79.

Woods, A.J., Coates, K.D., and Hamann, A. 2005. Is an unprecedented Dothistroma needle blight epidemic related to climate change? Bioscience 55: 761–769.

Wright, E. F., Coates, K.D., Canham, C.D., and Bartemucci, P. 1998. Species variability in growth response to light across climatic regions in northwestern British Columbia. Can. J. For. Res. 28: 871-886.

Table 1. Occurrence of major broadleaved species by ecological zone in British Columbia's interior

Ecological zone	Aspen	Birch	Cottonwood/Poplar
SWB	no	no	no
ESSF	no	no	no
MS	moist subzones only	no	no
BWBS	yes	yes	yes
SBS	yes	yes	yes
SBPS	no	no	no
PP	no	no	no
IDF	moist sub zones only	moist subzones only	no
ICH	yes	yes	moist subzones only

Table 2. Volume of broadleaved species in B.C's interior by Forest District

District	Volume of birch	Volume of cottonwood	Volume of aspen	Total volume
			m^3	
Fort Nelson	23,682,034	26,740,126	152,210,135	202,632,295
Fort St John	4,473,140	9,135,466	77,444,888	91,053,494
Dawson Creek	519,690	18,019,949	48,672,415	67,212,054
Prince George	6,712,843	3,696,176	31,474,012	41,883,031
Mackenzie	2,797,261	2,760,970	22,814,958	28,373,189
Cassiar	749,348	4,363,402	20,274,458	25,387,209
Ft St James	1,019,383	1,893,041	19,722,628	22,635,062
Kamloops	5,127,219	1,080,232	9,132,330	15,339,781
Williams Lake	2,113,841	1,895,730	10,961,217	14,970,788
Kispiox	3,230,973	3,356,621	6,529,461	13,117,055
Quesnel	3,348,776	843,642	8,569,028	12,761,446
Okanagan	6,300,457	1,050,052	3,156,924	10,507,433
Lakes	132,414	304,759	8,565,848	9,003,021
100 Mile House	734,819	130,590	7,729,080	8,594,489
Morice	124,909	1,055,005	5,824,864	7,004,778
Bulkley	449,299	1,825,313	3,684,936	5,959,548
Robson Valley	1,055,798	803,101	3,403,370	5,262,269
Arrow	1,841,980	750,603	2,229,539	4,822,122
Kalum	1,063,729	2,044,489	1,022,126	4,130,344
Revelstoke	702,876	542,896	2,065,844	3,311,616
Kootenay Lakes	1,168,190	532,454	1,216,031	2,916,675
Cranbrook	203,418	928,334	1,319,918	2,451,670
Merritt	10,671	390,506	1,876,040	2,277,217
Boundary	175,462	389,704	522,569	1,087,735
Lillooet	108,920	126,382	303,086	538,388
All Districts	67,847,450	84,659,543	450,725,705	603,232,709

Data obtained from Edward Fong of the MFR Forest Analysis and Inventory Branch. The Forest Districts are those that existed before 2002.

Table 3. Broadleaf annual allowable cut, actual cut and potential cut in the Peace River Region of BC

TSA	Existing AAC	Broadleaf AAC	Actual broadleaf cut	Potential AAC	Potential broadleaf cut
	Million m^3	Million m^3	%	Million m^3	Million m^3
Fort Nelson	1.500	0.900	100	3.163	1.444
Fort St. John	2.015	0.915	12	2.720	0.915
Dawson Creek	1.733	0.886	42	2.078	0.880

Sources: TSA Analysis Reports (BC Ministry of Forests and Range 2007b)

Table 4 Classification of the citations shown in the bibliography (see Appendix 4)

species and species combinations	# of citations	genetics	physiology/ biology	ecology	climate change	pests	silviculture/ manage-ment	products	other	total
Aspen	432	29	68	199	16	27	79	10	2	59.7%
Aspen hybrid	28	8	13	0	0	0	7	0	0	3.8%
Birch	83	4	36	12	4	8	17	4	0	10.7%
Cottonwood	53	11	21	12	2	7	0	0	0	7.4%
Cottonwood hybrids	74	12	46	0	0	5	9	2	0	9.8%
Populus sp.	20	2	11	3	0	1	2	0	1	2.6%
Aspen and birch	27	0	16	1	1	1	9	0	0	3.8%
Balsam poplar	6	0	5	0	0	0	1	0	0	0.8%
All species	21	0	0	9	0	1	6	4	0	2.2%
total	744	66	216	236	23	50	130	20	3	
		8.9%	29.0%	31.7%	3.1%	6.7%	17.4%	2.7%	0.4%	

Table 5. A list of broadleaf and mixed broadleaf-conifer trials that have been initiated in B.C. since 1990.

BC Experimental Project Number	Description of project
EP1046.03	Biological nitrogen fixation in reforestation: Alnus viridis trials
EP1058	Competition between Sitka alder communities and lodgepole pine
EP1069	Commercial silviculture of hybrid poplars, native cottonwoods and aspens in B.C.
EP1069.02	City of Vernon wastewater irrigation demonstrations on Vernon Commonage
EP1069.11	Provenance Trial of 18 seed sources of paper birch
EP1069.12	Paper birch 195 open pollinated families from 2 south regions - Skimikin Nursery
EP1069.13	Paper birch genecology 48 Seed Source Trial
EP1069.20	Growth & adaptedness testing of hybrid poplar - Huscroft Farm Hybrid Poplar
EP1075.01	Integrated aspen-range resource management options in the BWBS zone: The effects of timber harvesting, cattle grazing and grass seeding on aspen and forage production)
EP1089.02	Pure and mixed birch stand management studies in the ICH Zone of the Southern Interior of British Columbia
EP1089.03	Regeneration of paper birch/conifer mixtures in the ICH zone of the Southern Interior of British Columbia
EP1089.04	Long-term effects of management practices on productivity of mixedwood stands in the ICH zone in the southern interior of British Columbia
EP1089.06	Ecological significance of interspecific carbon transfer via ectomycorrhizal hyphae in mixtures of Douglas-fir and paper birch
EP1089.08	Crop-tree Response to Brushing at Various Radii in the Mixed Broad-leaved Shrub Complex
EP1089.10	Spruce - Birch Mixture Study at Larch Hills
EP1114.01	Assessment of the past success of white spruce planted under aspen canopies of different ages and structures (B16)
EP1115.01	Analysis of quality and productivity of birch-dominated stands in the Prince George Forest Region
EP1117.01	Two case studies to determine nitrogen fixation by Sitka alder
EP1133.01	Thinning and fertilization trials in trembling aspen/balsam poplar stands in Prince George Forest Region
EP1136.01	A study to determine the suitability of native hardwoods for reforestation, and their effect on long-term soil nutrient status
EP1139	The significance of site variables in predicting decay in aspen trees in the BWBS biogeoclimatic subzone
EP1152	Assessing Aspen-Pine competition in young stands in the Cariboo Forest Region
EP1153.01	Multiple Species Trial on a Low Elevation ICH site in the Kamloops Forest Region
EP1181	The Effects of Spacing on the Growth and Yield of Hybrid Poplar
EP1185	Effects of Sitka Alder Retention and Removal on the Growth of Young Lodgepole Pine in the Central Interior of British Columbia
EP1191	Establishment and development of mixed species stands across a range of micro-environments in the ICHmw2
EP1192.04	Vegetation management options for establishment of hybrid poplar plantations
EP1193	Effects of spacing of paper birch on the growth of birch and understory conifers
EP1197	The influence of thermal time and mechanical damage on suckering potential of trembling aspen (Populus tremuloides)
EP1197.01	The influence of on-site wood chip processing on regeneration of aspen (Populus tremuloides) in the Boreal White and Black Spruce biogeoclimatic zone.
EP1248.21	Site Index and Height Models - Trembling Aspen
EP1248.23	Site Index and Height Models - Paper Birch
EP1266.02	Development and application of the aspen growth model (TASS-Ac)
EP1266.03	Development and application of the birch growth model (TASS-Ep)
EP1342	Establishment of long term growth and yield installations for the study of the natural development of northern hardwood monocultures (B19)
EP1350	Development of free-growing stocking standards for B.C. mixedwoods (B42)
EP1361	Regenerating Boreal Mixedwood

Appendix 1

On broadleaves

While the original specifications for this Provincial status report referred to "hardwoods", we prefer the terms "Broadleaf and broadleaved" as descriptive singular and plural adjectives, and the term "Broadleaves" as a collective noun. Although "hardwood" is the commonly used term in the United States and Eastern Canada for these species, we argue that this term is less useful in British Columbia. Of the species we have considered in this report, only paper birch fits the literal interpretation of a hardwood. It is described as moderately hard and dense in wood technology texts (Simard and Vyse 1992). However it is no "harder" than several conifer or B.C. "softwood" species. Both aspen and cottonwood are relatively low in density and have low hardness. Cottonwood is especially low in density and it is a true "softwood". Not surprisingly, the terms "hardwood" and "softwood" are confusing to the public, and while they have the merit of having a long history in eastern North America, they do not fit well with modern ecologically based forestry. Wood is not the only, nor is it even the most important, forest value in the public eye.

In B.C. the terminology problem has been recognised and the term "deciduous" is often applied to the non-coniferous species such as birch and aspen. It is not clear why this usage is preferred and why it is any improvement over the use of "hardwood". From a botanical and forestry standpoint it is inaccurate because there are three conifer species native to the province that are deciduous in habit (*Larix spp.*), and one important broadleaf that is evergreen in habit (*Arbutus*). And it is also confusing for the public who can see evergreen broadleaves and deciduous conifers in their parks and gardens.

Other alternatives have been suggested. Lauriault (1989) suggests the use of the terms "flowering" to distinguish non-coniferous plants, but, since conifers appear to have flowers (they bear cones), this term would simply add more confusion, for foresters and the public alike. Another option would be to use the botanical terms "Angiosperms" and "Gymnosperms". Although correct, they carry an academic weight and a tendentious tone. They would be unlikely to achieve wide public, or professional, use.

In our view the terms "broadleaf" and "broadleaves" are more accurate and more acceptable. Broadleaf describes the leaf shape accurately and is immediately understandable by the public. The term is beginning to become more widely used in English Canada (see Mitchell 1987, and Farrar 1995), and it is already widely used in French Canada and in Europe.

There are some problems with the widespread use of the term broadleaf. *Gingko biloba* is a considered a gymnosperm, but has a fruit-like seed and a broad leaf. *Phyllocladus asplenifolius,* or Celery topped pine, an Australian conifer, also has a broad leaf. Conversely, some of the *Casurina* species of Australian origin are angiosperms, but they have needle-like branches and tiny leaves. But only *Gingko* is likely to be encountered by the vast majority of Canadian foresters and interested public, and it is sufficiently unique to be regarded as a benign exception. In B.C. western red cedar (*Thuya plicata*) has a flattened leaf, but the scales of the leaf are narrow.

Some might argue that if broadleaf was to be adopted, "narrowleaf" would be the logical term to apply to species other than broadleaves. But the term "conifer" is botanically acceptable, and it is already widely adopted professionally at least. It is also easily understandable at the public level as the cones of the major coniferous trees are easily visible. Changing an accurate and well used term to serve some obscure grammatical point would have little value. In B.C. western red cedar (*Thuya plicata*) has a flattened leaf, but the scales of the leaf are narrow.

In our view, the adoption of the terms broadleaf and conifer has the merit of simplicity and the advantage of reducing terminological confusion. And in one stroke we can relieve the pain of having to listen to forestry professionals perform a semantic juggling act every time they set out to describe the broadleaved trees that have been so neglected in the past. Cinderellas, it is your time to shine!

Appendix 2

Area of broadleaved stands

The statistics shown are based on stands with broadleaves as leading species. This neglects the many stands where broadleaves are a component of the stand mixture and so underestimates the importance of the species. In Royal Roads 2006 the area of forest where birch volume is greater than or equal to 65 cubic meters per hectare is estimated to be 996,000 hectares which is 4.5 times larger than the estimate shown below. Nevertheless, the pattern of distribution matches that of volume shown in Table 2.

Timber supply areas	Area of birch	Area of cottonwood	Area of aspen	Total area
		Ha.		
Fort Nelson	103,000	67,200	1,050,000	1,220,200
Fort St John	34,000	17,800	660,000	711,800
Dawson Creek	0	75,300	473,000	548,300
Prince George incl. Fort St James	15,700	9,600	364,000	389,300
Mackenzie	0	0	205,000	205,000
Williams Lake	8,700	0	93,000	101,700
Lakes	0	0	73,000	73,000
Quesnel	0	0	62,200	62,200
Okanagan	23,900	4,000	0	27,900
Kispiox	9,800	7,700	0	17,500
Kamloops	14,200	0	0	14,200
Kalum	0	7,700	0	7,700
All Districts	209,300	189,300	2,980,200	3,378,800

Appendix 3

Management pathways for mixed species stands in southern BC (from Simard and Vyse 2006).

The first and most common pathway would involve enrichment of the naturally regenerated species mix with conifer species of current high commercial value, much as is done now, but at lower densities and thus lower establishment cost. Similar approaches are used in German forests according to Kenk (1992). Stumping for root disease abatement would be reduced and applied only in areas designated for high yield management, with the remaining areas managed with resilient species mixtures that include broadleaves. Brushing costs would be reduced by removing the free growing restrictions on the density and proximity of broadleaved species and allowing individual forest managers the ability to apply selective treatments where crop tree survival is threatened. Chemical brushing treatments would be applied on a limited basis to root disease infested sites as a way reduce the risk of disease accentuation. Thus managers might prescribe brushing to release western larch, which is very shade intolerant, and not other species that are more tolerant of shade. The resulting stands would be managed as stratified mixtures following the precepts of Smith et al. (1997). Stand improvement practices to control species composition or stem quality would depend upon individual perceptions of species and stem value, market prices and non market values at the time, rather than making a irrevocable decision about future markets and values at the time establishment. In the longer term, we forecast that such stands would be managed on a continuous cover basis with frequent entries, natural regeneration, and low additional management costs.

Methods for projecting the yield of mixed species stands remain to be developed, even though vertical stratification of mixed ICH stands, and the respective height growth patterns of species in mixtures have been described (Cameron 1996). German experience with mixtures of beech and spruce suggests that results can be positive or negative depending upon the site (Kenk 1992). In Finland, experience with mixed stands of birch and pine or spruce suggests that total stand yield will be maximized with a birch component of between 25 and 50% (Mielikainen 1996).

A second pathway would not involve enrichment planting with conifers, but instead rely upon natural regeneration. In the southern interior ICH forests, natural regeneration is abundant adjacent to retained forest patches within large patch cuts in most forest types, as well as in small harvested patches in the younger mixed forest types that originated from large wildfires 80-120 years ago (Vyse and DeLong 1994; Heineman et al. 2002). This pathway would best be suited to less productive sites and more remote locations, in keeping with the "semi-natural" approach recommended by Lieffers et al. (1996). These forests would receive minimal intervention, allowing natural stratification of the complex mixtures.

The third pathway would apply to a much more limited portion of the landscape, where site productivity is highest. It would focus on achieving high productivity of individual species, or designed mixtures, over relatively short rotations. Conifer production would follow the standard prescription described earlier, but with more careful site selection, focusing on the most productive, mesic to subhygric portions of harvested sites. Emphasis would be placed on eliminating stand gaps, and creating a sufficiently high density to permit future choices of high quality crop trees. Plantations of birch are a feasible option, and are common in Finland (Puttonen 1996), where production of genetically improved silver birch (*Betula pendula* Roth*)* reached 25 million seedlings annually in the 1990's. Birch should be established on mesic to subhygric sites, where the species performs best (Simard and Vyse 1992; Simard et al. 2004b). Since genetically improved stock is not available at present, it should be established at high densities to allow stem selection in subsequent stand entries. Managers would be free to invest heavily in conifers and broadleaved species depending upon their perception of market and pest risks. This intensive management element would have to be encouraged by government since the majority of forest lands in British Columbia are owned by the province. Private companies undertake forest regeneration as a condition of their harvesting tenures and not as an investment.

Table A3.1. The current management pathway and three alternative pathways for managing mixtures across the landscape.

Management Pathway	Management actions				Management aims	
	Site preparation	Stumping for root disease manage-ment	Regeneration	Vegetation control	Stand	Landscape
Current management/ conifer sawlog production	Mechanical	Yes	Planting at moderate density; 2-3 early successional conifer species	Manual brushing to meet free growing regulation	Mixed conifer, minor broadleaves even aged, single storey	Clearcut
1st pathway/ conifer enrichment	Mechanical or none	None	Planting 2-3 early and late successional conifer species at low density	Selective manual brushing	Stratified mixture of conifers and broadleaves	Continuous cover
2nd pathway/ semi-natural management	None	None	No planting	No brushing	Un-controlled stratified mixture of conifers and broadleaves	Continuous cover
3rd pathway High intensity management of single species (conifer or broadleaves)	Mechanical	Yes	Planting single species early successional species at moderate to high density	Broadcast chemical brushing	Single species, conifer or broadleaves, even-aged, single storey	Clearcut