Western Larch Reforestation in British Columbia: Opportunity and Guidance for Expansion by Assisted Migration to Southern Interior Ecosystems of B.C.

by

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Abstract

Western larch *(Larix occidentalis Nutt.)* is a vigorous tree species in interior (Kootenay) ecosystems of British Columbia. Lodgepole pine *(Pinus contorta)* has been extensively planted as monocultures across the BC interior for many decades and concerns over future forest health and productivity have arisen as many of these lodgepole pine stands have succumb to many damaging agents past "free to grow" status (Mather, et al. 2010). New forest management policies that include western larch reforestation and expansion through assisted migration should be developed in order to diversify our species selection for reforestation in the BC interior. Western larch has many advantages over lodgepole pine which include higher productivity on certain sites and greater wood qualities that fit in well with diversifying our ecosystems and increasing the value of our future timber supply. The Kamloops Future Forest Initiative and the Wood First Initiative are two projects that can streamline the growth and expansion of western larch reforestation into interior ecosystems and forest management plans. There are numerous examples of western larch growing well on sites around Merritt and Kamloops BC which demonstrate the species can adapt well to certain sites out of its natural range. In this paper I discuss why foresters and forest policy makers should enable flexibility in stocking standards for western larch and discuss issues of increasing western larch reforestation in the BC interior.

Key words: Western larch, lodgepole pine, assisted migration, Kamloops future forest initiative, wood first Initiative, forest policy amendments, stocking standards.

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Introduction

Western larch (Larix occidentalis Nutt.) is an important native species in British Columbia (BC) and the northwestern United States. Western larch is the most productive of the three Larix species native to North America. In its native range it is a fast-growing tree species that produces exceptional wood quality, strength, and durability. Western larch is prominent in the Southeast Interior of BC where it grows in even aged stands and in mixed stands with other species such as western white pine (*Pinus monticola*), Douglas fir *(Pseudotsuga menziesii),* ponderosa pine (*Pinus ponderosa*), hybrid spruce (*Picea glauca x P. engelmannii),* and lodgepole pine *(Pinus contorta).*

Lodgepole pine has been planted in BC for many decades. Recent research suggests that lodgepole pine has substandard stocking levels and high mortality after it has been declared free to grow (Heineman, et al. 2010). Most of these young stands have now been killed by the voracious appetite of Mountain Pine Beetle (MPB, *Dendroctonus ponderosae*) which has grown to epidemic proportions leaving the MPB to feast on these younger lodgepole pine stands. In order to avoid another MPB epidemic we have to think about mixing in certain tree species like western larch in forests while scaling back on lodgepole pine reforestation. This increases forest resilience to changes in climate over the next few decades. Western larch is well suited to grow on poor sites and is very shade intolerant, much like lodgepole pine. Certain regions of focus where western larch should be planted are the Kamloops and Merritt regions where western larch has been proven to grow well but is not readily planted in these areas. There is evidence of a mature residual population near Merritt BC,indicating that western larch once colonized this region. This is classified as the westernmost larch population in BC.Expansion of western larch from its current range in the Kootenay region through Merritt and Kamloops forest districts by assisted migration should be a management strategy to revitalize interior ecosystems .This report will focus on how western larch will supplement lodgepole pine in creating diverse and resilient ecosystems replacing lodgepole pine stand monocultures. The following list outlines the structure of this report on western larch expansion and reforestation in the BC interior:

- Discuss western larch ecology and silviculture, distribution, and economic importance in BC
- Explain the current problems with “free to grow” lodgepole pine stands
- Provide specific examples of western larch reforestation success in Kamloops and Merritt regions
- Explain why western larch is an excellent choice for application in the Kamloops Future Forest Initiative (KFFI) and Wood First Initiative (WFI) in BC.
- Discuss issues with intensifying western larch reforestation and expansion
- Conclude with recommendations for assisted migration and stocking standards of western larch throughout the southern interior of BC.

Western larch ecology and silviculture, distribution, and economic importance in BC.

Ecology and silviculture

The deciduous conifer western larch is one of the most remarkable tree species in the *Pinaceae* family. Western larch is distinct from other pine members and conifers as it turns a beautiful yellow colour during the fall losing its needles shortly thereafter. It is a pioneer species much like lodgepole pine and can dominate a landscape after a fire has taken place. Western larch is a seral species, rather than climax in its habitat because of its high intolerance to shade (Owens 2008). It can grow in cohorts of fire-induced even aged stands and can commonly grow with other conifers in mixed forests that have up to 10 different species including mainly Douglas-fir, lodgepole pine, engelmann spruce, subalpine fir, and ponderosa pine, just to name a few. *Table 1* outlines some important ecological and silvicultural characteristics of western larch in comparison with lodgepole pine.

Table 1. Ecological and silvicultural characteristics of western larch and lodgepole pine

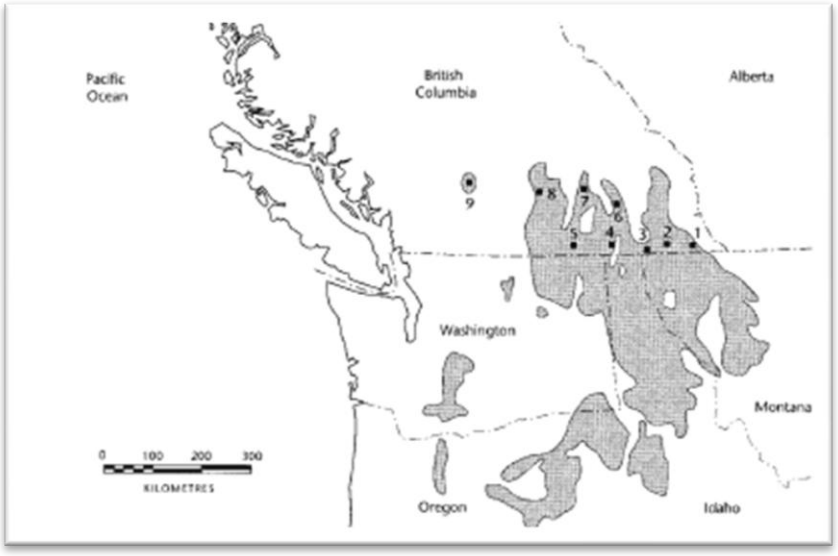
	Lodgepole Pine	**Western Larch**
Potential Productivity	**Medium**: Site index (50 yr @ bh) <30 m; growth rate decline after about 150 years	**High**: The most productive interior conifer 50 yr @ bh) approaching 35 m on the most productive sites.
Water deficit	High: Very frequent on dry sites	Medium: Frequent on dry sites
Nutrient deficiency (N)	High: very frequent on poor sites	Medium: Tolerates acid substrates
Snow/Wind resistance	Low: Intolerant especially on high snowpack sites;	High: Due to open crown, deciduous nature and deep rooting.
Pest and disease risk	High: Associated with most pest and diseases*	Low: Significantly less pests than lode pole pine; higher tolerance against Armillaria ostoyae than any conifer*

***See Appendix** Source: (BCFS 2000)

Western larch is a highly productive conifer that can tolerate sites that are nutrient and water deficient. In its natural range western larch is well adapted to medium-rich sites and rarely occurs on hygric or xeric sites (BCFS 2000). Western larch is very shade intolerant and should not be planted in high retention silviculture systems or any system which decreases sun exposure. Frost can affect western larch seedling establishment and areas where frosts are of concern should be avoided if possible (Astridge 2010). It is apparent in *table 1* that western larch can be more productive than lodgepole pine and can survive on poor sites. More analysis on site series specific data is needed in order to recommend the ideal sites where western larch can have the greatest chance for survival and future productivity out of its natural range.

Distribution

Glaciations have been a large part of BC ecology for the last 16,000 years. It has been theorized that western larch was a dominant species in the northern parts of BC as well as the southern interior in the Kamloops and Merritt area (Rehfeldt and Jaquish 2010). Only in the past few thousand years where less frequent summer rains and low fire frequency have occurred has western larch begun to shift to the South into the range it now occupies (*Fig. 1*). One population of western larch is located near Merritt and is classified as the westernmost western larch population in BC This population of western larch represents remnants of past distributions. The prominent western larch forest distribution can be seen in the Kootenay area (Southeast BC).

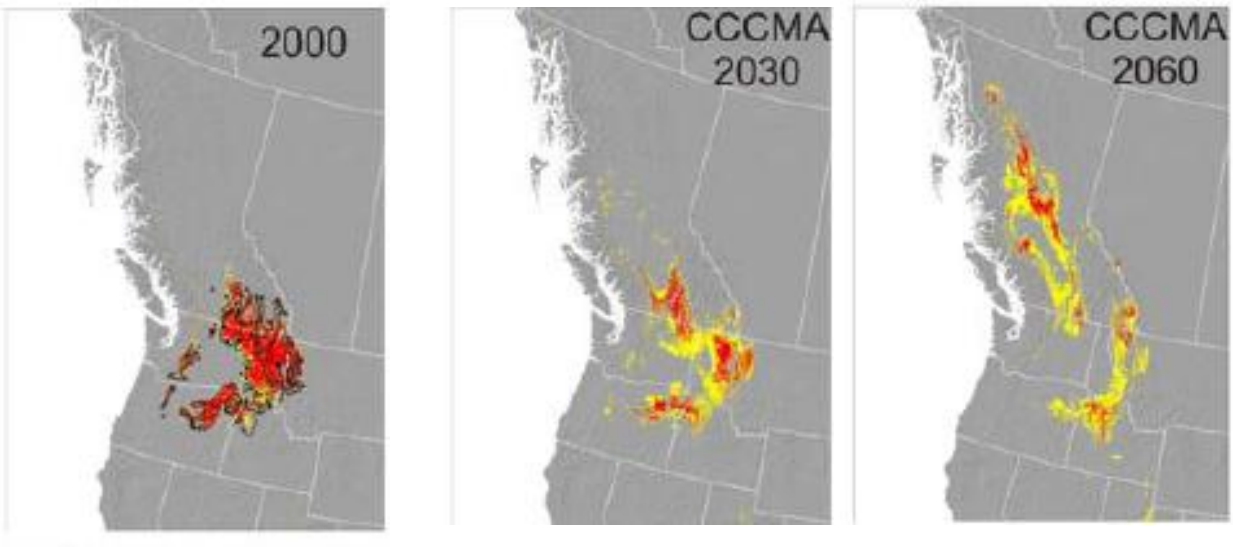


Source: (Rehfeldt and Jaquish 2010)

Figure 1. Current western larch distribution in the Pacific Northwest. Note the small residual population of western larch labeled plot 9 to the far west in British Columbia.

Recent modeling by Rhefeldt and Jaquish suggests that western larch will migrate northward over the course of a century *(Fig.2).* According to the model a large population of western larch is expected to encompass the Merritt and Kamloops regions over half a century which suggests that forest managers should begin to intensify western larch reforestation in the interior of BC through assisted migration programs. The model predicts the migration of western larch through algorithms which involve biological ecological classification data and temperature and precipitation regimes. It essentially predicts the migration and changes of different subzones throughout the province while modeling certain species distribution.

Many trials were conducted around the Kamloops and Merritt forest districts and there are various examples of western larch growing well on certain sites. Specific examples with photos and growth parameters of these trees coupled with site specific data are provided in subsequent sections.



Source: (Rehfeldt and Jaquish 2010)

Figure 2. Migration of western larch over a 60 yr span. Note the expanding northwest migration through the interior of B.C encompassing Merritt and Kamloops forest districts over this span. This is one of 3 scenarios that Rehfeldt and Jaquish's model predicted for western larch migration over time.

Economic importance

Economically, western larch is an important species in BC. as it has many preferred wood qualities such as high density, strength, and, durability. Its large size and desirable wood qualities make it a preferred species for lumber, utility poles, and firewood. Western larch provides a wide variety of other valued products such as plywood, pulp, house-logs, and water-soluble gum (Keegan et al. 1995). It has many similar qualities to Douglas fir, another commercially valued species in the BC *Table 2* summarizes important western larch wood qualities compared to lodgepole pine.

Table 2. Wood quality comparison of western larch and lodgepole pine.

	Lodgepole Pine	Western larch
Density-Air Dried (kg/m3)	430-low to medium	600- High
Aesthetic qualities	White-yellow with distinct contrast of earlywood and late wood.	Deep reddish-brown with sharp contrast with earlywood latewood, good veneer
Durability/decay resistance	Slightly durable	Moderately durable
Workability	Moderate to poor fastening qualities. Good finishing and machining capability	Excellent fastening and finishing qualities. Good machining capability
Structural capabilities	Low compression strength, moderately soft and light. Ideal for framing.	High compression strength, stiff, hard wood. Good for load bearing structures
Shrinkage	Low to moderate	Moderate to high

Source: (Forest Innovation Investment 2010)

Western larch makes up only 0.7 % of BC's total growing stock and is an important species for producing high quality timber. Western larch has many wood quality advantages over lodgepole pine (Forest Innovation Investment 2010). The commercial value of western larch combined with the ecological and aesthetic values of western larch forests makes it a truly valuable species which should be planted on suitable sites out of its natural range in the interior of BC.

Issues with Lodgepole Pine Reforestation and Post "Free to Grow" Status

Lodgepole pine has been extensively planted in monocultures throughout the interior of BC to reforest sites during the past four decades (Heineman, et al. 2010). The species has many ecological advantages that make it a prime choice for reforestation in BC: rapid juvenile growth rates, wide ecological amplitude, and a high tolerance of environmental conditions such as drought, frost, and low soil nutrient availability. However, for these same reasons it may be particularly susceptible to climate-induced changes in the range and severity of attack by a variety of damaging agents (Mather, et al. 2010). Recent research has identified about a quarter of the lodgepole pine stands surveyed for health have incurred damage as a result of a variety of pests, disease, and abiotic damage soon after being declared "free to grow". This suggests that planting monocultures of lodgepole pine should be avoided in general for future reforestation plans and be greatly scaled back on sites where research found high rates of plantation failure and damage (Heineman, et al. 2010). Examples of these sites are the ICH and ESSF wet variants where snow and ice loads are high and have caused significant damage of the post free to grow

lodgepole pine. The most common cause of damage is stem disease, in particular western gall rust *(Endocronartium harknessii)* and atropelis canker *(Atropellis piniphila)* which occurred primarily in the dry southern interior and affected approximately one-quarter of stems surveyed (Mather, et al. 2010). The high incidence of disease and damage to lodgepole pine stands combined with the uncertainty and change in climatic conditions with respect to shifts in precipitation and winter temperatures could enhance damage and reduce productivity of lodgepole pine stands that are already infected by widespread health problems. Having realized these problems with lodgepole pine reforestation it is now time to implement strategies that provide for resilient ecosystems past the "free to grow" stage to ensure long-lasting healthy forests. There are growing opportunities for forest managers to develop site specific plans for reforestation of mixed western larch and lodgepole pine forests. Western larch can supplement lodgepole pine stands in areas where past high disease and pest incidence has occurred and help revitalize lodgepole pine ecosystems throughout the BC interior. An investigation of successful western larch growth in Kamloops and Merritt forest districts provides support for its potential.

Western Larch Reforestation in the Merritt and Kamloops Forest Districts

There are plenty of examples of western larch growing well on a variety of sites throughout the southern interior in the Merritt and Kamloops forest districts. Western larch has been introduced to the areas and has been growing quite well outperforming lodgepole pine on certain sites. I will provide three areas of the following examples of western larch reforestation in the Merritt/Kamloops forest districts: Wet and dry site on Woodlot 1606 which include a western larch, lodgepole pine, hybrid spruce mix; Aspen Planers ltd. cut block reforestation with western l arch and lodgepole pine mix; and private property forest with mixed western larch plantation near Kamloops.

Woodlot # 1606 western larch, lodgepole pine, hybrid spruce mixed plantation – wet site

Figure 3. Western larch growing on a productive site in Woodlot 1606. Note the vigorous leader growth.

Table 3 Site characteristics of Woodlot 1606 wet site

BEC	**Montane Spruce dry mild- MSdm1**
Site index	26
Species composition (%)	Pl-62% Sx-20% **Lw-18%**
Height (m)	4.2
Avg. Leader growth (cm)	55, last yr growth- 1.1m
Age (yrs)	8
Elevation (m)	1280
Stocking (wsph)	1200

This is a very productive site for the interior of BC and the flourishing growth of western larch is evident in the picture above. There is a 20% representation of western larch in this stand and there is no evidence of dieback or any limiting factors that can impede the productivity of the species thus far. The stand has been declared “free to grow” and is continually monitored on an annual basis by forest professionals. It is important to assess the plantations that include a high component of western larch out of its natural range to ensure that stocking is ideal and consistent with forest practice regulations and standards. From the continued documentation of western

larch progress and the monitoring of post "free to grow" status we can start creating a framework for western larch reforestation that includes recommendations on a site series specific basis. The western larch on this site is growing well so it is appropriate to assume that western larch can succeed on a productive site in the MSdm1 BEC zone out of its natural range.

Woodlot # 1606 western larch, lodgepole pine, hybrid spruce mixed plantation – dry site

Figure 4. Western larch on a dry site on Woodlot 1606 that is lower in productivity.

Table 4. Site characteristics of Woodlot 1606 dry site

BEC	**Interior Douglas Fir dry cool- IDFdk1**
Site index	19
Species composition (%)	Pl-65% Sx-21% **Lw-13%** Fd -1%
Height (m)	3.5
Avg. Leader growth (cm)	45, last year growth 90cm
Age (yrs)	8
Elevation (m)	1230
Stocking (wsph)	1000

With a slightly lesser component of western larch, successful western larch reforestation is evident on the same Woodlot 1606 site that is less productive. The site is Interior Douglas- fir dry, cool and a relatively high component of western larch exists. Stocking density is less than the wet site and the western larches were declared “free to grow”. The site is monitored by forest professionals as with the woodlot 1606 wet site. It appears that western larch can succeed and flourish on slightly drier sites which are less productive and at a low density. The site is at 1230m elevation and is close to the border to the Montane Spruce Zone.

Aspen Planers Ltd. reforestation with a small component of western larch

Figure 5. Western larch on a very dry site growing well and free of damage

Table 5. Site characteristics for Aspen Planers Ltd. cutblock

BEC	Interior Douglas Fir very dry cool- IDFxk1
Site index	15
Species composition (%)	Pl-85% Fd-5% At-7% **Lw- 3%**
Height (m)	4.5
Avg. Leader growth (cm)	38
Age (yrs)	12
Elevation	1280
Stocking	1000

The site illustrated above is an average site index of 15 in the Merritt forest district. Aspen Planers Ltd. is one of the major licensees in the area and they have mixed in western larch with certain stands as a small component. Mature western larch stands are within close proximity of this cutblock and forest professionals have been proactive in mixing smaller components of western larch in their silviculture prescriptions to help revive populations in the area. The evidence of mature trees in the area confirms the forest professionals' prescription for western larch on this cutblock. The picture depicts a western larch tree that has grown very well on an average site in the Merritt forest district. Similar silviculture prescriptions under Aspen Planers Ltd. have similar success of western larch reforestation out of its natural range.

Private property near Kamloops (Barnhartvale area)

Figure 6. 15 yr old western larch in late winter. Note that cone production has begun in the upper crown (left)

Table 6. Site characteristics for private property site

BEC	**Interior Douglas- fir very dry cool-IDF xk1**
Site index	17
Species composition (%)	Fdi-50% Pli-35% **Lw-15%**
Height (m)	6
Avg. Leader growth (cm)	47
Age (yrs)	15
Elevation (m)	1000
Stocking	800

Western larch was established on this site in 1997 and has since been flourishing. It is a small component at 15% and at a low stocking of 800 well spaced stems per hectare. This is the oldest western larch reforestation example shown at 15 years and is currently free of pests and disease. Western larch cones have now developed on these trees and within a few years the disseminated

seeds should produce some viable seedlings within the area. The cones can be seen if you look closely in *figure 6* (left).

Mature western larch stand near Tyner Lake, Merritt-Aspen Planers Timber License Area

Evidence of old growth western larch can be found northwest of Merritt near Tyner Lake *(Figure 1 Plot 9).* These trees are 170yrs old and are free of pests and disease. The dead lodgepole pine is evident to the right of the large western larch tree in the photo below. This is the westernmost western larch population in BC and represents past western larch distribution. Below are pictures of this mature western larch stand coupled with their site specific data.

Figure 7. Mature 170yr old western larch stand. To the left is a cohort of western larch left over after selective harvest of lodgepole pine stands. The picture on the right depicts the immense size that western larch trees can achieve.

Table7. Site characteristics of mature western larch population near Tyner Lake

BEC	Interior Douglas Fir dry cool- IDFdk1
Site index	14
Species composition (%)	**Lw-80%** Pl-10% Fd-10%
Height (m)	35-40
Leader growth (cm)	50
Age (yrs)	170
Elevation (m)	1300
Volume/Hectare (m^3)	300- 350

Western larch dominates this site and surrounding forests near Tyner Lake northwest of Merritt B.C. It is a major component of adjacent ecosystems as most lodgepole pine in the area had succumbed to the MPB and was eventually selectively harvested. This disturbance left western larch as one of the only remaining species with minor components of Douglas-fir and hybrid spruce. Silviculture planners from Aspen Planers Ltd. have left certain western larch trees after harvest as a seed-tree silviculture strategy to encourage dissemination of western larch seed from these residual populations. Lodgepole pine is the major species planted after the selective seed-tree harvest and western larch should have a chance to reproduce naturally to produce a mixed stand.

The site index is very low at 14 and is very rocky. Western larch has seemed to grow quite well throughout its 170yrs on this specific site. This residual population can serve as evidence that could support amendments for silviculture prescriptions for the long term that include silviculture treatments and reforestation of western larch on dry sites like this one.

Western larch's place in the Kamloops Future Forest Initiative and Wood First Initiative

Two recent initiatives that will help streamline western larch expansion in BC are the Kamloops Future Forest Initiative (KFFI) and the Wood First Initiative (WFI). The KFFI project in the Southern Interior of BC has identified a number of adaptive actions to reduce climate change impact vulnerabilities which include increasing the diversity of tree species during reforestation (Initiative 2008). The chief forester recently amended the standards for seed use limits of western larch to 10% of the total planted seedlings in BC which is a significant increase from past western larch reforestation (Ministry of Forests 2010). Specifically, this amendment

provides for the range and population expansion of western larch beyond its current range to the areas where Rehfeldt and Jaquish projected to be climatically suitable in their climate models. This initiative is an opportunity for forest managers in these areas to develop plans for western larch reforestation on suitable sites and provide a framework for western larch reforestation site suitability out of its natural range. The KFFI is exactly what proponents for western larch reforestation need and will serve as an excellent opportunity for intensification of western larch reforestation to provide Kamloops and the entire interior of BC. with ecosystems that are highly capable of withstanding the uncertainties of climate change.

Western larch has great wood qualities and could be a valuable resource if wood can remain a major building constituent in the future economy. The WFI in BC aims to build on promoting the use of BC wood products around the world. The overall goal of WFI is to encourage a cultural shift toward viewing wood as the first choice for construction, interior design and daily living, while strengthening BC's traditional lumber sector (British Columbia Forests, Lands and Natural Resource Operations 2009). By expanding western larch reforestation throughout the province we could have an enhanced future timber supply that is highly valued because of superior wood qualities of western larch. Currently mass production of commodity goods such as lodgepole pine lumber is dominating the forestry sector and is considered a low value wood product used predominately in framing. With western larch`s superior wood quality we can extract more value from our future timber supply and build on the WFI. With the security of more resilient ecosystems and an enhanced future timber supply B.C.'s forest sector can become more attractive to potential investors for wood innovation and business. This should foster some innovation and development opportunities for investors to get on board to propel the WFI into the economy and to promote the desirable wood qualities derived from trees like western larch.

The KFFI and WFI are compatible with western larch reforestation and expansion throughout BC It provides forest managers with an opportunity to develop site specific reforestation plans for western larch to create diverse, resilient ecosystems and a robust and enhanced future timber supply. The KFFI, WFI, and the implementation of western larch reforestation are convincing in providing answers to some of the problems in the BC forest sector but are not without some key issues as I will discuss in the next section.

Issues with Intensifying Western larch Reforestation and Expansion in B.C

Maintaining the status-quo with lodgepole pine reforestation

Lodgepole pine has been extensively planted over the past 4 decades (55% of all trees planted in the province annually) because of its initial high rates of survival, rapid early growth, and tolerance of a range of site conditions (Mather, et al. 2010). We have based our reforestation policy including stocking standards, free to grow status and guidelines around lodgepole pine and have so for decades. For these reasons forest managers found it to be the most cost-effective way to meet reforestation obligations which subsequently lead to numerous monoculture lodgepole pine stands throughout the interior. With the recent evidence of degrading forest productivity of lodgepole pine, western larch reforestation and expansion in BC should be considered as an alternative management strategy to protect interior ecosystems from the uncertainties and vulnerabilities of climate change. In order to propel western larch reforestation in the interior lodgepole pine should be greatly scaled back in reforestation efforts and retooling of certain reforestation facilities to allow for production of western larch have to be implemented. We have invested large amounts of money in reforestation infrastructure such as orchards and seed extraction facilities, and nurseries for procuring and growing the best lodgepole pine seeds and seedlings suited for any site around the interior of BC. These facilities will have to endure changes in increasing western larch seed and seedling volumes and focus less on lodgepole pine. Lodgepole pine has been used for reforestation in the BC interior for 4 decades and the government has entrenched policies that layout guidelines on lodgepole pine reforestation and seed selection which make it difficult to divert from the status quo and incorporate western larch reforestation and expansion into a climate change adaptation strategy.

Stocking guidelines and policy

The incorporation of western larch into stocking standards in areas of range expansion will be necessary if licensees plan to plant western larch and use it to meet their free growing obligations (Astridge 2010). The minister's considerations for a licensees Forest Stewardship Plan (FSP) are

as stated in the Forest Planning and Practices Regulation (FPPR) Sections 26 (3) and (4), stocking standards and free growing height need to:

- demonstrate that the areas will be stocked with ecologically suitable species that address the immediate and long term forest health issues;
- maintain or enhance economically valuable supply of timber; and
- be consistent with the timber supply analysis and forest management assumptions that apply to the area.

(FPPR 2004)

Western larch did not historically occur in certain expanded range areas based on the climate modeling analysis by Rehfeldt and Jaquish. Outside of their current range, stocking standards will need to be specific in identifying where western larch is ecologically suitable and consistent with *Chief foresters Standards for Seed use in BC* (Astridge 2010). The stocking standards are typically based on the provincial Biological Ecological classification system (BEC) applied at the site series level and currently do not specify guidelines for western larch reforestation in its expanded range that is managed for climate shifts in BEC subzone and variant boundaries (Astridge 2010). This is an opportunity that can allow forest professionals to consult with regional specialists and ecologists for information on site specific factors that will influence successful establishment of western larch in their operating areas. More information and studies will likely follow the productivity and health of western larch beyond its native ranges and warrant more specific guidance for planting western larch. This will increase the likelihood of successful reforestation in the Kamloops and Merritt forest districts.

Western larch and its long-term impact on forest health is another issue to consider as there may be forest health factors concerned with other species in that ecosystem (Astridge 2010). Perhaps consequences of introducing western larch into unfamiliar ecosystems could emerge and impact other species productivity and overall health and vigour. It is prudent for forest managers to allow a limited component of western larch planted in conjunction with other species like lodgepole pine.

Other potential forest health issues associated with western larch are climatic risks such as mortality from frost and snow damage. Western larch is adapted to a wide range of temperatures, but since buds open earlier than most conifers, hard frosts in late spring may result in some dieback and cone crop loss. Snow and ice are generally not significant threats to western larch survival but wet snow, when needles are present (early spring or late fall), may cause broken or bent leaders that can result in permanent damage.

In western larch, phenology (eg. timing of bud burst and bud set) and adaptation (eg. tolerance to disease and insects) are very important to consider when creating assisted migration strategies. Populations of western larch tend to be differentiated according to the relative mildness of the climate (Rehfeldt and Jaquish 2010). Those populations native to warm and moist climates tend to have the highest growth potential, highest tolerance to needle diseases, and lowest tolerances to winter cold (Rehfeldt and Jaquish 2010). By establishing western larch on sites north of their natural range, problems may occur with respect to timing of bud burst and set. On sites where latitude and elevation are different than their natural range, the phenological limits of western larch must be assessed to ensure that growth and survival is attuned to that specific site and in sync with the growing environment. Proper seed selection and amendments to the *Chief foresters Standards for Seed use in BC* have to be considered to mitigate any problems associated with planting western larch at different latitudes and altitudes. Furthermore, introducing western larch out of its natural range where climates are cold and sites are xeric could decrease their growth potential and reduce their tolerance to pests, disease, and winter cold making insect and disease risk to western larch more prevalent than in their native ranges.

Western spruce budworm *(Choristoneura occidentalis)* is a native defoliator of interior douglas-fir and numerous outbreaks have occurred throughout the Kamloops and Merritt forest districts. The host tree is primarily Douglas fir while other trees species such as true firs and western larch can be severely impacted by the western spruce budworm. The greatest impact from spruce budworm is among suppressed and intermediate trees. Repeated defoliation causes tree mortality over large areas, reduction of growth rates, and reduced lumber quality (Ministry of Forest, Lands and Natural Resource Operations 2010). In their juvenile years western larch could be affected by the spruce budworm if planted near outbreaks outside their native range as stresses caused by the potential difficulties with adapting to non-native sites could increase their

susceptibility to pests like spruce budworm. Other notable diseases and pests that could affect western larch in these areas are dwarf mistletoe *(Arceuthobium laricis)*, larch case bearer*(Coleophora laricella),* and western hemlock looper (*Lambdina fiscellaria lugubrosa* (*Hulst*)).

In BC's stocking guidelines and standards there are certain species categorized as "preferred" and "acceptable" which must be prescribed for each standards unit and be ecologically suited to the site. The "preferred" species is ecologically suited to the site, and management activities are aimed primarily at establishing these species. The "acceptable" species are also ecologically suited to the site, but management activities are aimed secondarily towards establishing them (Ministry of Forests and Range 2000). Lodgepole pine is typically a "preferred" species in the interior and it is a good strategy to keep the species as "preferred" because of its natural range throughout the BC interior and its past performance in the pre-MPB epidemic era. However, lodgepole pine reforestation should be scaled back on specified sites to allow for opportunities for western larch reforestation. In our current guidelines western larch is neither "preferred" nor "accepted" on virtually every silviculture prescription for stocking standards in the interior out of its natural range. Stocking guidelines for western larch will have to be amended making it a "preferred" and/or "acceptable" species on suitable sites where our management activities are aimed primarily at establishing the species. At this early stage of western larch reforestation it is recommended that the species be deemed acceptable where sites make it favourable for establishment and future productivity. As an acceptable species, western larch should not exceed 50% of well spaced free growing stems in any prescription (Astridge 2010). Therefore, if western larch does not perform well on these sites over the long term there will be some other species stock remaining on the site. When further monitoring and research from local silviculture and ecology experts of western larch reforestation is made available for the long term, western larch may be deemed a "preferred" species and can be the major species planted while greatly scaling back lodgepole pine reforestation.

Congruent with silviculture prescription amendments to increase western larch reforestation are forest policy amendments to allow variable acceptable densities in prescriptions that encourage structural diversity. Our current stocking guidelines are fairly stringent and offer no room for flexibility and professional judgment in determining the density of trees planted on a particular site. Allowing for variable densities in stands can provide for a wide range of stand conditions

and encourage different mixtures of trees at different densities. This strategy would make the stand structure more spatially diverse and perhaps more resilient to uncertainties of climates shifts and risk of loss to mortality by unknown damaging agents. Some tree species can be more susceptible to damaging agents at certain densities. Planting a mixture of species that includes western larch, at variable densities could potentially mitigate some of the damage by these agents in certain areas (Gov. of B.C 1998). The silviculture prescription should have recommendations on spacing densities within the reforestation area and foresters should manage for a site specific distribution with a known mean of well spaced stems per hectare and pre-planned variability (Coates 2011). An example of planting at variable densities would be increasing the stocking densities from 1200 to 1800 well spaced stems per hectare where high mortality from abitoic damage or pest and disease damage is expected for a portion of the area. This provides increased flexibility for foresters to use a wider variety of treatments within a silviculture prescription and provides better forest management on a site specific basis. Western larch should be a greater component in reforestation strategies in the interior and management strategies that include greater flexibility for site specific stocking densities should open viable opportunities for foresters to increase the resiliency and spatial diversity of planted stands.
Also inherent in stocking standards and guidelines is a "free to grow" height for western larch which must be specified in the silviculture prescription.

"Free to grow" heights for western larch must be specified in the silviculture prescription for the well spaced "preferred" and "acceptable" western larch species. The "free grow" height must be sufficient to demonstrate that the tree is growing well, adapted to the site and be expected to continue to do so throughout its lifetime (Ministry of Forests and Range 2000). In most areas where western larch could be planted, we do not have specific growth information and are lacking "free to grow" heights for certain site series and site indices. The forest research branch has a Site Index Biological Ecological Classification System (SIBEC) site index species conversion for mixed species stands in which site index species conversion tables can provide the average site index expected for a species when site index is known for another species growing on the same site (MOFR-Research Branch 2006). Since lodgepole pine is a pioneer species like western larch and site indices are well known throughout the Merritt and Kamloops forest districts it is recommended that forest professionals base their "free growing" heights on

lodgepole pine . I will demonstrate in an example how this adjustment for western larch will take place in providing a specified “free to grow” height at the site.

If a SIBEC site index estimate for a common site index in the Merritt is 16 for lodgepole pine, the species conversion table suggests that western larch would have a site index of 17.3 for that site which is roughly 8.1% higher than lodgepole pine (MOFR-Research Branch 2006). Therefore if we have a “free growing” height of 1m for lodgepole pine on the site, a rough estimate for western larch would be 1.1m. This method can serve as a temporary “free to grow” height for western larch out of its natural range. In some areas a “free to grow” height of 1m for western larch can be quickly achieved thus the height may have to increase in order to give time for forest professionals to properly assess the health factors for western larch during its early stages of establishment (Astridge 2010). Forest professionals should contact regional silviculture experts for up to date information on the establishment of western larch and its productivity and vigor after being declared “free to grow”.

Consistency with timber supply and forest management assumptions

Consistent with increasing species diversity by facilitating the planting of western larch is maintaining or enhancing an economically valuable supply of timber (Astridge 2010). Stocking standards are normally linked to assumptions for the sustainability of timber flows over time (Ministry of Forests and Range 2000). For licensees FSP’s which contain large assisted range expansion areas, the stocking standards may not be consistent with timber supply assumptions (Astridge 2010). Under FPPR 26(5) the inclusion of western larch is still approved and reasonable for future timber supply targets in these areas (FPPR 2004). Forest managers will have to develop certain management objectives in FSP’s that include western larch in their timber supply analysis and future timber supply. The manufacturing of a larger component of western larch in the future should be considered when developing FSP’s as manufacturers in the interior can retool and develop plans to allow for optimization of larch wood production and are prepared to extract the greatest value from the species through initiatives like WFI.

Conclusion with recommendations

Western larch is an important native species is B.C. and the Pacific Northwest. It is an integral tree species in ecosystems in the interior and has excellent wood qualities that make it ideal for a variety of wood building applications. Lodgepole pine is another important interior tree species and has been planted extensively in B.C. for several decades. The MPB and other damaging agents have caused high levels of mortality affecting lodgepole pine stands in the interior decreasing their chance for survival and productivity in an uncertain future climate. Lodgepole pine reforestation needs to be greatly scaled back and an increase of western larch reforestation should be incorporated into silviculture planning regimes throughout the interior.
The current range of western larch encompasses most of the Kootenay region in B.C. with a small isolated population located in the Merritt area. It has been shown in models by Rehfeldt and Jaquish that western larch populations will migrate from the Kootenay's northward over a span of 60yrs. This suggests that assisted migration of western larch would be a good strategy to prepare for climate shifts and increase resilience and diversity in ecosystems. The KFFI is a plan that supports assisted migration of western larch and can be used to streamline reforestation projects that are highly adapted and resilient for climate shifts. The WFI also supports the intensification of western larch reforestation as future forests will have a species that can potentially have higher value than lodgepole pine and contribute to a wood economy.

There are certain issues with intensifying western larch reforestation which include diversion away from entrenched policies and management for lodgepole pine reforestation. New guidelines and amendments of provincial stocking standards that include "free growing" specifications, flexibility for stocking densities, and ecological suitability of western larch have to be created. Monitoring of western larch out of its natural range has to be implemented in order to ensure healthy ecosystems for many years. Furthermore, western larch reforestation has to be consistent with timber supply and management assumptions when creating FSP's. Western larch has been shown to be a success out of its natural range on sites in the Merritt and Kamloops forest districts. The species has shown to be growing vigorously on the sites that I have tested. At this time I recommend the following for western larch reforestation in areas out of its natural range through assisted migration:

- Western larch should be a low component in any reforested stand out of its natural range mixed with lodgepole pine. Therefore, if western larch does not adapt well in the future lodgepole pine and other natural tree species still comprise a large portion of the stand.

- Western larch should be monitored on a regular basis after "free to grow" status to ensure it is growing healthy. Furthermore, concerns regarding pest and disease, and winter damage on their migrated sites have to be considered before planning for western larch reforestation particularly within proximity of western spruce budworm outbreaks.

- Western larch does well on mesic sites but can grow very well on xeric and wet sites. More monitoring of the western larch on drier and wetter sites would be a prudent management strategy as damaging agents are more likely to affect the tree.

- Western larch's phenological limits must be assessed to ensure that growth and survival is attuned to a specific site and in sync with the growing environment. Western larch seed selection and amendments to the *Chief foresters Standards for Seed use in BC* have to be considered to mitigate any problems associated with planting western larch at different latitudes and altitudes.

- Western larch should be reforested where it has plenty of access to sunlight as it is very shade intolerant and should be planted away from frost pools.

- Western larch has grown well where stocking is from 800 to 1200 well spaced stems per hectare in a mixture of lodgepole pine, hybrid spruce, and Douglas-fir. Stocking in this range should be preferred but flexibility for increased stocking on a site specific basis should be a management strategy for foresters to increase the resilience and spatial diversity of planted stands.

Western larch is an excellent choice for creating diverse and resilient ecosystems that are highly capable of withstanding the vulnerabilities of climate change. It is important that we develop new policies and standards to help guide western larch reforestation into future forest management plans in B.C. Forest professionals and ecologists have to continue to monitor western larch and research where the species has the best chance for survival and productivity out of its natural range.

Appendix

List of primary insects and diseases for western larch and lodgepole pine (Spokane County Conservation District 2010):

Western Larch (*Larix occidentalis):*

Primary insects:
Douglas fir beetle
Western spruce budworm
Larch bud moth
Larch sawfly
Larch casebearer

Primary diseases:
Larch canker
Larch dwarf mistletoe
Larch needle blight

Lodgepole Pine *(Pinus contorta):*

Primary insects:
Ips beetle or pine engraver (bark borer)
Western pine beetle (bark borer)
Red turpentine beetle (bark borer)
Mountain pine beetle (bark borer)
White pine weevil

Primary diseases:
Armillaria root rot
Black stain root disease
Annosus root rot
Schweinitzii root rot
Laminated root rot
Western gall rust
Red belt fungus
Pine dwarf mistletoe
Lodgepole pine needle casts
Red band needle blight

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