

Assessment of Off-Site Tree Plantations in the Northwest Interior of British Columbia - Project Summary

Prepared for:

Forest Genetics Council of British Columbia
Genecology and Seed Transfer Program

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INTRODUCTION

One of the core assumptions underlying British Columbia's reforestation program is that the climate and environment are stable and therefore the tree species that were removed during harvest will be suitable for the next rotation. Global climate change, and the rate at which it is occurring locally, has put this assumption in serious doubt. Across B.C., we are seeing increased instances of plantation failures that are likely associated with atypical climatic conditions (e.g. severe drought), as well as climate-driven alterations to forest disease levels and insect populations (e.g. *Dothistroma* and mountain pine beetle). In order to ensure the viability and sustainability of our forest resources and the communities and industries that rely on them, we need to determine not only the continued suitability of the species currently being used for reforestation, but also the potential for "non-local" or "off-site" species to survive and grow. For the purposes of this report, "off-site" refers to tree species that are native to B.C. but not native to the area under study. Several research projects have investigated and modelled the suitability of tree species under warming temperatures due to climate change (Hamman and Wang, 2006; MoFR, 2006; Nitschke and Innes, 2007), but there is little field-based information available on the actual long-term performance of off-site tree species. Assisted migration and provenance trials are the usual approach to addressing this issue and they are valuable; however, because B.C.'s tree species are typically slow-growing and very long-lived, these types of experiments will take many years or even decades to provide detailed, long-term survival and growth information. Our climate is changing more rapidly than our tree species can adapt so it is critical that we take advantage of all available information to assist us in planning for, and adapting to, this change.

Over the last fifty years, the BC Ministry of Forests and Range (MoFR) and local forest companies in the northwest part of the province have established a network of off-site plantations, typically as small inclusions in operational blocks. Although these plantations have not been maintained or visited on any regular schedule, a preliminary survey in 2009 found that many still exist. Given the age and geographic spread of these plantations, they offer a unique opportunity to examine the survival, health, and growth of tree species that were established well outside of their known ranges and preferred climatic envelopes. Although these plantations were not specifically established as assisted migration or genecology trials, their condition will provide valuable insight into how well the species have coped, not only with an atypical climate to start with, but also one that has continued to change over the last several decades. The off-site species that have been planted outside their natural ranges that are examined in this report are: Interior Douglas fir (*Pseudotsuga menziesii* var. *glauca* (Mirb.) Franco), Coastal Douglas fir (*Pseudotsuga menziesii* var. *menziesii* (Mirb.) Franco), and Western larch (*Larix occidentalis* Nutt.).

Field data collection for this project was completed by LM Forest Resource Solutions Ltd. under contract to the Bulkley Valley Centre for Natural Resources Research and Management and in conjunction with Phil LePage of the Ministry of Natural Resource Operations (MNRO), Skeena Research Section, in Smithers. Mapping work was done by LM Forest Resource Solutions Ltd. and Blair Ells of MNRO in Smithers.

METHODOLOGY

Using historic data from the MoFR and industry, a database was compiled of all the known off-site plantations in the study area. Each plantation was assessed for off-site species general survival, health, and growth characteristics. Since no formal survival plots were established at the time of planting, survival could not be directly measured but was inferred by comparing stand density and composition to the recorded number of trees planted. The final electronic database includes plantation location information along with site series, zone, subzone, and variant data (BEC), plantation establishment date, species, stock type, and seedlot information (origin location, latitude, longitude, and elevation). Historic plantation records (i.e. Results) indicate where the operational plantation blocks are located, but not specifically where in the blocks the off-site trees were planted, so locating them was often time consuming and in some cases, impossible. In a

few instances, there was no evidence of surviving trees. Some identified sites were inaccessible due to road abandonment or deactivation. Once a site was positively identified in the field, the geographic coordinates were recorded using GPS technology. One or more assessment plots (based on size of plantation) were established in each plantation. Detailed measurements included: BEC classification (down to the site series level), total tree height, diameter at breast height (DBH), stand density, crown class, a census of natural regeneration (both local and off-site species), and the proportion of off-site trees by layer (dominant/co-dominant and intermediate/suppressed). Assessments were made of individual tree health and vigour using the Stand Development Monitoring Protocol damage criteria established by the MoFR forest health staff. Photographs were taken in each plantation showing the growth and quality of established trees. Cores were taken on each plot tree to determine breast height age. Plot data was collected in either fixed or variable radius plots or, when survival was poor, on individual trees dispersed throughout the stand. The objective was to measure 6 to 10 trees at each plot. Lack of target tree species meant that fewer than 6 trees were measured in some plots.

PHYSICAL DISTRIBUTION OF DATA

A total of 76 plots were measured and an additional nine were evaluated but no measurements were made because the target species could not be found. Key features of the data set are summarized in the tables below. Plots were located in the Nadina, Skeena, and Kalum Forest Districts from East of Burns Lake to West of Terrace and from North of Ootsa Lake to South of Cranberry Junction (see Figure 1).

Site series sampled.

Zone	Subzone	Site series
CHW	ws1	/01, /02, /04
ICH	mc2	/01, /02, /03, /04, /53
SBS	dk	/01, /03, /04, /05, /06
SBS	dw3	/01
SBS	mc2	/01, /02, /03, /06

Number of plots with data by species and BEC unit.

BEC Unit	Fdc	Fdi	Lw	Total
CWHws1	5	4	8	17
ICHmc2		15	1	16
SBSdk		15	7	22
SBSdw3		3		3
SBSmc2		11	7	18
Total	5	48	23	76

Number of plots with no data by species and BEC unit.

BEC Unit	Fdc	Fdi	Lw	Total
CWHws1	1		1	2
ICHmc2		1		1
SBSdk		6		6
SBSdw3				0
SBSmc2				0
Total	1	7	1	9

PRELIMINARY SPECIES AND SEEDLOT OBSERVATIONS

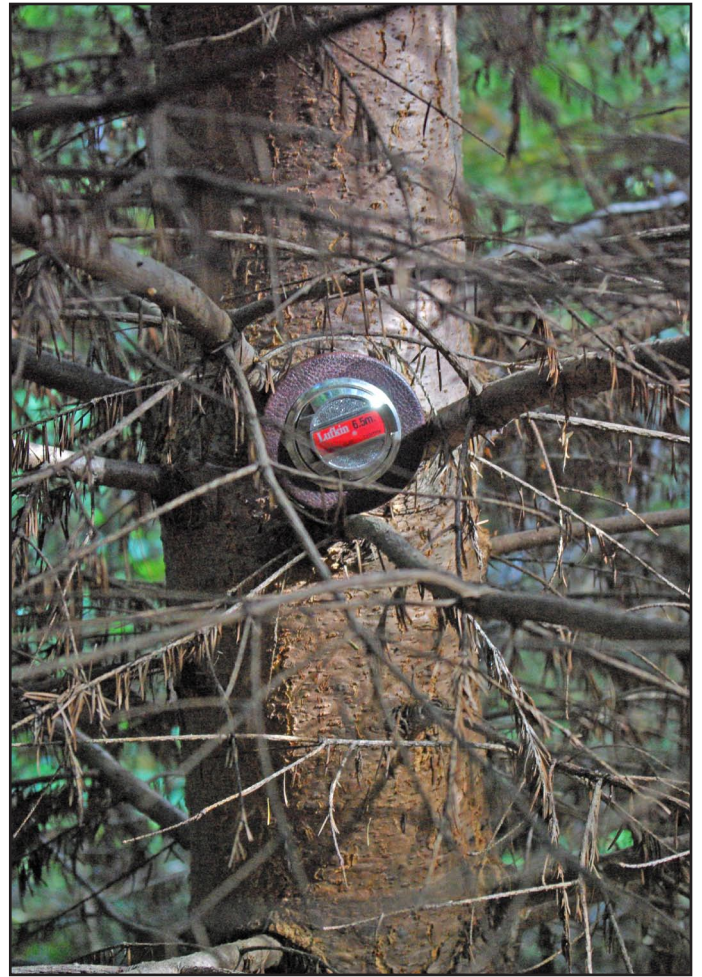
The following text summarizes field-based observations and measurements by species and seedlot. A complete listing of the collected data is provided in digital format with the project submission (Microsoft Excel). A few photos are included for some sites to strengthen the explanation. A complete set of digital photos and an overview map of the plot locations are also included with the project package submission. Individual site maps are not included but can be provided upon request if additional site visits are to be conducted.

Interior Douglas-fir

Seedlot 8492 (Openings 103I099-3, 93M002-28, 93M011-88, 93M042-29): All of these sites are located in the ICHmc2 and were planted in 1992 in an elevation band ranging from 300 to 700m. Stock type is unknown although 1+0 PSB 313 and 415 were very common at the time. All sites except 103I099-3 are fresh to moist and average to above average in terms of productivity (site series /01, /03, and /04). 103I099-3 is poor in some areas (site series /02) with rapidly drained, stony soils but a warm exposure. There are no cold air ponding issues at any of the sites. Survival on 103I099-3 appears to be reasonable. *Dothistroma* incidence on pine in this stand was high and the pine did not look as healthy as the Douglas-fir. Both growth and survival in 93M002-28 and 93M011-88 were very good. Plantation espacement was tight which led to early canopy closure and little early brush competition. In 93M042-29 there are very few Douglas-fir trees and heavy brush and overtopping deciduous trees. Co-dominant tree height on all of these sites except 103I099-3 ranged from 6.2 to 11.0m and averaged 9.3m at a breast height age of 10 to 13 years. Diameters were also generally good and ranged from 5.9 to 19.0cm with an average of 13.2cm. At 103I099-3, height/diameter ratios were also favourable but the trees were smaller (average 7.3m tall and 9.8cm DBH) due to lower site quality. There were no significant forest health issues at any of the sites. This seedlot appears quite suitable to the ICH because the Douglas-fir is growing well and does not suffer from any significant forest health factor including early growing season frost or snow press. Height and diameter growth are superior to hemlock and subalpine fir and as good as pine, at least during early stand development. Douglas-fir offers an alternative to pine in areas of high *Dothistroma* risk. The field assessment indicates that stand management practices have an important bearing on survival and growth (e.g. broadcast burning, brush control).



18-year-old interior Douglas-fir plantation in the ICHmc2 (site 93M002-28).



18-year-old interior Douglas-fir at site 93M002-28(1) on the left and 93M002-28(2) on the right.



Mixed interior Douglas-fir and lodgepole pine at site 103I099-3(1).



1992 interior Douglas-fir plantation at site 93M011-88(2).



1992 interior Douglas-fir plantations (93M011-88, 1&2). Note the variation in basal diameters of healthy stems.

Seedlot 8281 (103P050-14): This site is also located in the ICHmc2 and was planted in 1989 in an elevation band between 580m to 610m. The stock type used was 1+0 PSB 415. Site quality is good (site series /01 and /03) and the site is moderately brushy to brushy but occurs on a warm aspect with no cold air ponding. Brush competition and competition from hemlock ingress may have both been factors in early survival in some pockets within the stand. Accurate survival rates are difficult to determine because no information is available on plantation espacement but Douglas-fir distribution is currently patchy, especially in brushier areas. The area was not broadcast burned. Co-dominant trees range between 7 and 10m tall (average 8.7m) at a breast height age of 12 to 15 years. Diameters ranged from 10 to 18cm (average 14.5cm) and height/diameter ratios are favourable (not spindly). Forest health issues are not common but some forking is occurring - likely from frost or snow damage. Overall, this seedlot does not appear to have performed as well as 8492 but the Douglas-fir are healthy and growing as well or better than hemlock and subalpine fir and generally as well as pine.



21-year-old interior Douglas-fir plantation 103P50-14.

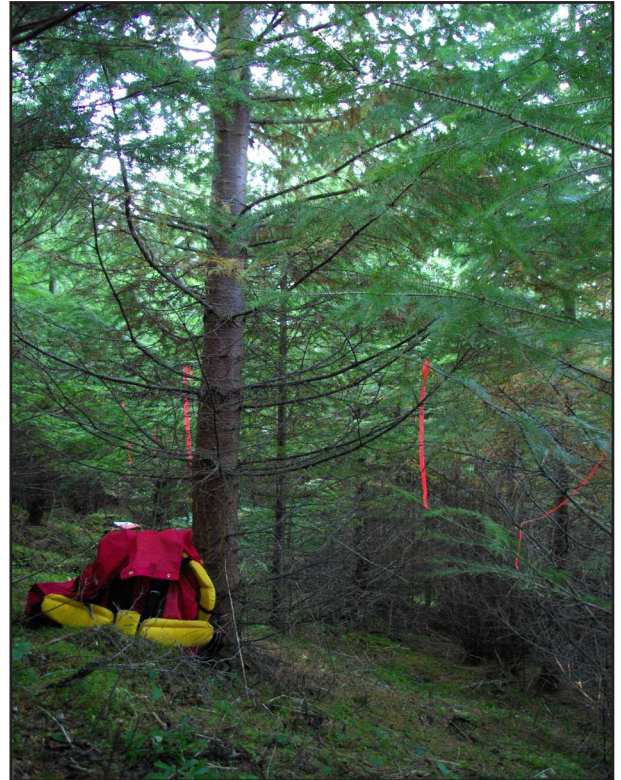


Close-up of healthy Douglas-fir in the ICHmc2.

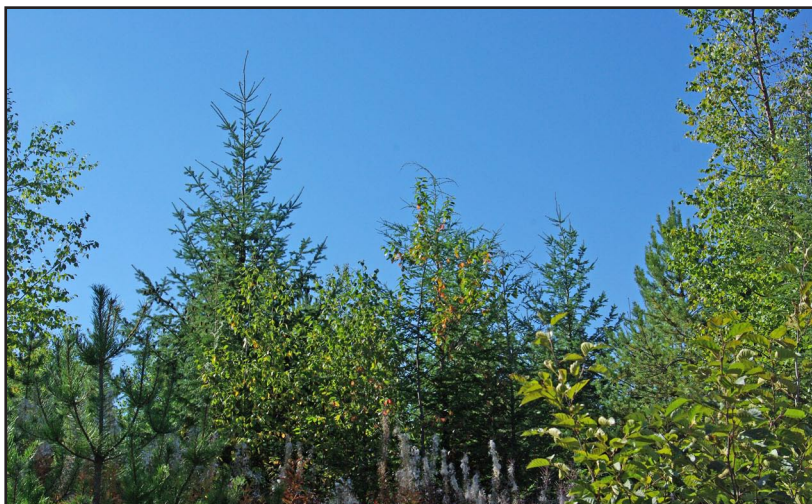
Seedlot 1256 (93M033-9 and 93M052-28): These two sites are located in the ICHmc2 and were both planted in 1989 in an elevation band between 430m and 580m. Both areas are /01 sites, have well drained soils with low or moderate brush and little potential for cold air ponding. There were no significant forest health issues. Height of co-dominant Douglas-fir ranged from 7 to 12m (average 9.5m) for breast height ages of 11 to 15 years. Diameters ranged from 9 to 20cm (average 12.6cm) and height/diameter ratios were higher (more spindly trees) in 93M033-9 than in 93M052-28. Leaders on co-dominant trees of up to 50cm were commonly observed. Most fir experienced slow initial growth and had a height disadvantage relative to the advance hemlock regeneration and early natural ingress. Competition was generally an important factor. Initial planting density is unknown but there are pockets with good survival. The area was not burned. This stock type seems well suited to conditions on mesic sites in the ICHmc2 and has an advantage over pine in the area which is often heavily impacted by *Dothistroma*. Performance appears to be very similar to seedlot 8492 and conclusions for that seedlot also apply here.



21 year-old Fdi at site 93M052-28(2).



21 year-old Fdi at site 93M033-9(1).



Growth of co-dominant interior Douglas-fir is similar to that of local species at the same age.

Seedlot 8580 (93M033-8 and 93M033-7): These sites were planted in 1989 in the ICHmc2 at an elevation of approximately 700m with 1+0 PSB 313 and 415 stock types. Unit 93M033-7 is an anomaly because three different seedlots (1256 (7%), 8381 (31%), and 8580 (62%)) were planted in 1989 in a “mixed bag” manner so it is impossible to distinguish seedlots in the field. All three seedlots originated from within 0.2° latitude and 0.5° longitude so differences should be minimal. Site quality was rated as good (site series /03) and there was potential for competition from brush during juvenile growth. Frost damage caused minor forking in some areas but most trees quickly re-established a dominant leader. Mean height and diameter of co-dominant trees was 9.6m and 14.5cm, respectively at a breast height age of about 16 years. Growth of surviving trees was comparable or better than pine on good sites and better than hemlock at this stage of stand development. Relative to other Douglas-fir seedlots established in the ICH, this seedlot reached breast height quickly but did not achieve better growth rates after that. Early rapid growth may have been related to stand management practices rather than growth potential. The seedlot does appear to be suitable in the ICH but less so than seedlots 1256 or 8492, and about the same as 8281.



Healthy 21-year-old Fdi at site 93M033-8.

Seedlot 3821 (93K003-20, 93K003-4, 93K003-6, Fdi-32Blk5): This seedlot was established in three different biogeoclimatic units, the SBSdk, SBSdw3, and SBSmc2 from 1983 to 1986. Elevation ranged from 800 to 1000m. Stock type information was only provided for Fdi-32Blk5 and 93K003-4 planted in 1983 and 1986, respectively, with 1+0 PSB 313. Good natural stocking and rapid early growth of lodgepole pine resulted in poor early growth of the fir in Fdi-32Blk5 and 93K003-4 (pine now vary from 1500 to 5000 stems/ha and 8 - 10m tall). There are very few co-dominant fir trees in these two sites (most are suppressed). Much of the Douglas-fir in 93K003-6 (SBSdw3/01) was also suppressed but by an aspen overstory rather than pine. Fdi32Blk5 and 93K003-4 are medium to poor sites (SBSmc2/01 & SBSdk/05, respectively) with stony soils and a warmer aspect and have moderate potential for frost. 93K003-6 is a medium site (SBSdw3/01) prone to frost damage in some sections. 93K003-20 is a good site (SBSdk/06) with moderate brush and less potential for frost damage. This site was broadcast burned which may have contributed to better initial survival and less ingress. Douglas-fir leaders on this site are 30 to 40cm. Except in 93K003-20 and areas under aspen cover in 93K003-6, forks, sweeps, and dead tops are common. These form problems likely result from frost damage and some snow breakage. Co-dominant fir on 93K003-20 and 93K003-6 are typically 7 to 10m tall (average 8.9m) and 9 to 14cm DBH (average 12.8) with favourable height/diameter ratios at a breast height age of 10 to 14 (larger values are for 93K003-20). Elsewhere, trees are suppressed and spindly. In areas where the fir is suppressed and pine beetle has killed some of the pine overstory, some of the fir are releasing and have reasonable leader growth. Although growth can be reasonable, there appears to be a greater risk of frost damage with this seedlot, relative to other seedlots. Stand management practices that could contribute to improved survival and growth include: broadcast burning, improved control of competing vegetation (including other conifer species), and avoiding frost prone areas.



Healthy Fdi in the SBSdk - site 93K003-20(2).



Badly suppressed Fdi in the SBSmc2 - site Fdi32 (Blk5).



Overtopped Fdi in the SBSdw3 - site 93K003-6(2).

Seedlot 14502 (93K003-51): This site is located in the SBSdw3 (800m in elevation) and was planted in 1991. Stock type is unknown. Site productivity was rated as medium (site series /01) and brush was low to moderate. There was some potential for cold air ponding but little evidence of frost damage and no other significant forest health factors. Initial planting distribution is uncertain but surviving trees are patchy. The stand is now a nice mix of pine, Douglas-fir, and spruce and the Douglas-fir are growing as well or better than native species on the site. Co-dominant trees are typically 4 to 6m tall (average 5.3m) at a breast height age of 7 years and diameters range from 5 to 8cm (average 6.7cm). This seedlot appears to be reasonably well suited to the current growing conditions on this site.



19 year-old Fdi growing in a mixed-species plantation.

Seedlot 377 (Fdi10, Fdi19 and Fdi22): These sites are in the SBSdk and were planted in 1962 (Fdi10) and 1964 (Fdi19 and 22) with 2 or 3 year old bareroot stock grown from seed from the Fort St. James area. Initial planting distribution is uncertain although it may have been a mix of species. Site quality at Fdi10 and Fdi19 was medium (site series /01) and brush was not a major concern. Aspect was warm and soils were well drained. At the Fdi19 site, aspen competition was an important factor. At Fdi19, most of the measured Douglas-fir were overtopped so there were no suitable site trees. There were fewer forks, crooks, and sweep associated with this seedlot than many other interior Douglas-fir seedlots. Some sweep from vegetation and snow press did occur but forest health issues were not a major concern. Co-dominant Douglas-fir in Fdi10 averaged about 13m in height and 19cm in diameter at a breast height age of approximately 30 years. Initial height growth was slow and is an issue when there is brush or fast growing tree species that will overtop the Douglas-fir. The older and larger stock type may have been a factor in both survival and early growth. Forty-six years after planting, performance of co-dominant trees was comparable to pine in the area but lower than western larch trials in the area. At Fdi22, average co-dominant tree heights and diameters were 13m and 21cm at a breast height age of 31 years. Douglas-fir growth on this site is comparable to pine height growth on good sites and is better than spruce on good sites. This seedlot appears to have a lower risk for forest health issues than some of the others that have been tried in the SBS. Growth of the Douglas-fir is similar to that of the local native species and would therefore be useful for augmenting species diversity.



Overtopped 46-year-old interior Douglas-fir at site Fdi19 in the SBSdk.



48-year-old co-dominant interior Douglas-fir at site Fdi10.

Seedlot 689 (Fdi12): This seedlot was established at an elevation of 960m in the SBSdk on a relatively warm exposure in 1963 using 2+1 BBR stock. Site quality was poor (site series /03) with stony soils on a ridge top. Brush and tree competition were not significant factors. Pine overstory was mostly killed by mountain pine beetle. Average height of co-dominant fir was 13.1m and average diameter at breast height was 18cm at a breast height age of 33. This is comparable to pine growth on a medium site. Survival in this plantation of 1200 trees is very poor with perhaps only 80 to 100 trees surviving. Forked and stunted trees were relatively common likely resulting from frost damage although the area was not subject to cold air ponding. This seedlot and stock type combinations do not seem well suited to conditions found at this site.



Some healthy, co-dominant 47-year-old Fdi (above) and some poorly formed and stunted individuals (right) were found on the same site at Fdi12.

Seedlot 716 (Fdi18 and Fdi21): These sites are in the SBSdk and were planted in 1963 and 1964, respectively with 2 or 3 year old bareroot stock at an elevation of 880 to 930m. Site quality at Fdi18 was poor but at Fdi21 it was medium (site series /03 and /01, respectively). Much of the overstory pine at both locations was killed by mountain pine beetle. Survival appeared poor at both sites. In Fdi18 forking and poor form, likely due to frost damage, were common. All trees at this plot were suppressed as a result of overtopping pine which established more quickly than the fir and shaded it out. In Fdi21, most trees were also suppressed but because of overtopping aspen rather than pine. Only one co-dominant Douglas-fir was observed between the two plots and growth for it was reasonably good (13.3m and 24.5cm tall at a breast height age of 28) but only equivalent to pine growth on a medium site. Current leader growth on the best Douglas-fir was 23cm after release from the overtopping pine. This seedlot has not any performed any better than native species in the area in terms of growth and there is significant survival risk because of sensitivity to early growing season frosts which, while potentially less common than in the past, still occur.



Badly overtopped 47-year-old Fdi. Some fir are now releasing after the overstory was killed by mountain pine beetle in 2007.

Seedlot 781 (Fdi24 and Fdi25): This seedlot was established in 1966 on two sites in the SBSdk in an elevation band of 850 to 890m using 2+0 and 2+1 bareroot stock. Site quality on both sites was medium (site series /01). No significant forest health issues were observed on either of the sites and forking was found on less than 5% of the stems. Some minor stem deformities due to rapid growth were noted on some of the fir at Fdi24 (the North Road site). Espacement in all three locations was typical of most plantations (~1100 stems/ha) and would not have contributed to early mortality. Growth was best on Fdi24 with average co-dominant tree heights and diameters of 17.5m and 24.5cm, respectively at a breast height age of about 35 years, and worst on Fdi25 (same seedlot) with average height and diameters of 10.5m and 15.6cm, respectively at a breast height age of about 30 years. Douglas-fir growth at Fdi24 is comparable to pine height growth on good sites and that of medium sites at Fdi25. Both sites show Douglas-fir growth that is better than spruce on good sites.



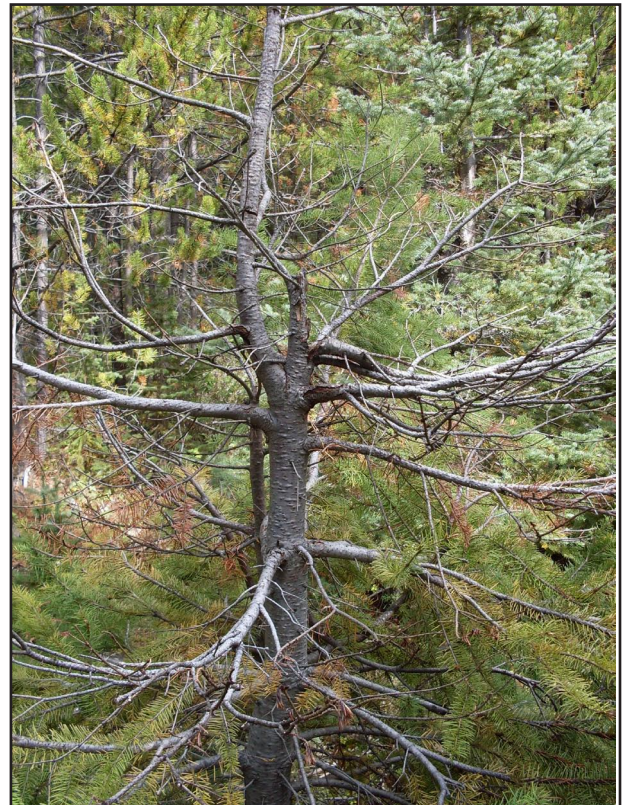
Healthy stand of 44-year-old interior Douglas-fir in SBSdk (site Fdi25).

Seedlot D26 (Fdi3 and Fdi4): This seedlot was planted near Kalum Lake in the CWHws1 in 1958 at an elevation of 250m using 3+0 bareroot stock. Seed source is listed as being from the Shuswap Lake area although no specific record exists in SPAR. Douglas-fir were planted as an admixture with Siberian larch in alternating rows. Site quality was medium (site series /01) and growth of surviving co-dominant trees (average of 23.5m and 34.6cm at a breast height age of 40) was comparable to amabilis fir and better than hemlock growing on good sites. Only 500 trees were planted at each site and survival was moderate and the incidence of forks, sweep, and dead tops was low. An unidentified needle blight was apparent in the lower branches on most trees although it did not appear to be having a significant impact on growth. The surviving trees are growing quite well so this seedlot may be a suitable choice for mixed plantations in the CWHws1. Site preparation treatments to minimize early brush competition would likely be beneficial.



Seedlot D29 (Fdi2): This seedlot was established in the SBSmc2 (transitional to the ESSFmc) at an elevation of 1060m on a southwest exposure in 1957 using 2+1 bareroot stock. The seedlot is again listed as being the Shuswap Lake area with no recorded information in SPAR. The site was rated as good (site series /05) but is steep with relatively high snow loads. The area was burned following logging in the early 1950's. Early herb and shrub development is typically high in this area and may have contributed to snow press and a delay in early height development. The incidence of forks, crooks, dead or broken tops, and sweep was very high, likely resulting from snow and frost damage. Growth was inconsistent and often poor compared to pine and spruce at this site although on steeper, rockier south or southwest facing slopes it was as good or better. Height and diameter for co-dominant Douglas-fir trees averaged 18.2m and 25.4cm, respectively at a breast height age between 33 and 43 years. This growth rate is comparable to pine on a good site at this stage of stand development. The level of snow damage encountered suggests that this seedlot is inappropriate at this elevation but that it may be appropriate at lower elevations.

Seedlots 114, 867, 2615, 2906 (Fdi27, Fdi28, Fdi29, Fdi30, Fdi31): These seedlots were planted in 1980 using 2+0 bareroot stock in unknown mixtures and unknown espacement at elevations ranging between 960 and 1090m (SBSmc2 or SBSdk transition to SBSmc2 biogeoclimatic units). Because multiple seedlots were used and no planting unit map has been located, it is not possible to determine how a specific seedlot performed. Seedlot source information indicates the seed came from fairly broad area (2.15° latitude and 4.95° longitude). Site quality at Fdi27 and Fdi31 was medium to good (site series /01 and /06) but was poor with stony soils (site series /01 low and /03) at Fdi28, Fdi29, and most of Fdi30. Bareroot stock was a poor choice for the areas with stony soils. Areas within Fdi28, Fdi29, and Fdi31 are subject to cold air ponding but frost damage was common on all sites causing forks, crooks, and dead tops. There was substantial variation in tree size and stem form, most likely related to frost damage in early stand development and levels of overstory tree competition. Heights and diameters of co-dominant trees averaged 9.6m and 16.0cm, respectively at a breast height age between 18 and 21 years. These seedlots seem more prone to frost damage than any of the other Douglas-fir seedlots established in the SBS. Overstory pine (especially on Fdi30 and 31) was an important



Damaged leaders and laterals due to frost or snow loading at site Fdi28 (left) and Fdi29 (right).



Healthy Fdi growing in a mixed-species plantation (site Fdi31).



Interior Douglas-fir coming through a *Dothistroma*-killed pine overstory (Fdi31).

factor contributing to poor growth, although it may have reduced the amount of frost damage. Rapid seed-in of lodgepole pine regeneration gave it an early height advantage over the planted Douglas-fir and together with slow initial growth of the planted stock, resulted in the fir occupying an understory position and growing relatively poorly in many areas. These seedlots are more susceptible to frost or snow loading damage at this elevation than others that have been tried in the SBS but growth of healthy trees is similar to species that are native to the area (10 to 12m at a breast height age of 20 to 25 years).

Seedlot 1885 (Fdi32Blk2 and Fdi32Blk6): This seedlot was planted in the SBSmc2 in 1993 at an elevation of about 1000m using 1+0 PSB 313 stock. Site quality at Fdi32Blk2 was very poor (site series /03) but medium on Fdi32Blk6 (site series /01). Both sites are subject to cold air ponding. Most of the Douglas-fir in Blk2, and approximately 40% of stems in Blk6, were forked or had a dead top. Many of the pine and spruce also had forks and crooks, indicating very harsh site conditions. The Douglas-fir crop failure rate in Blk2 was very high with only a few stems surviving. Slow initial growth of the Douglas-fir contributed to a situation in which pine had a clear height advantage and quickly overtopped the Douglas-fir. This was a significant factor at both sites. There were no co-dominant Douglas-fir trees in the assessment plots making it difficult to determine growth potential. Some fir are showing indications of release and current leader growth in open areas (no overtopping pine) is about 30cm. Results from these two sites suggest that use of this seedlot in the SBSmc2 may be risky, particularly on frost prone sites. If the seedlot is used on better quality sites with low frost potential and limited overstory competition, the growth performance may be significantly better.

Seedlot D32 (Fdi5 and Fdi6): This seedlot was planted in 1959 in two distinctly different BEC units, the CWHws1 (Fdi5) and the SBSmc2 (Fdi6). At both sites, 2+0 bareroot stock was used and plantation espacement was listed as 8x8 feet. Elevation was 250m at the CWH site and 750m at the SBS site. Site quality was rated as medium to good (site series /01, /04, and /06) at both locations. The CWH site was broadcast burned and survival was good. Competition from other tree species was not a factor at either location. Sweep was a common form factor at both locations but especially so in the CWH stand. There were no other significant

forest health factors in the CWH but an unidentified foliage disease is affecting the current year needles. At the SBS site, the incidence of forking (probably arising from frost damage) was higher than in the CWH. There was significant variation in stem size noted at this site. Growth at the CWH site was considerably greater than at the SBS site. Mean height and diameter of co-dominant trees in the CWH was 23.6m and 30.1cm, respectively, at a breast height age of about 39 years. This is comparable to amabilis fir growth on a good site and is better than hemlock growth on a good site. Mean height and diameter of co-dominant trees in the SBS was 17.9m and 24.1cm, respectively, also at a breast height age of approximately 39 years. This height growth rate is better than that predicted for either spruce or pine on similar sites. Height growth of the Douglas-fir was far superior in the CWH than in the SBS in absolute terms but, relative to other species in the same biogeoclimatic unit, was actually better in the SBS. Overall survival, however, appears to be much better in the CWH, likely because of frost damage in the SBS.



Healthy 51-year-old Fdi planted in the CWHws1 after a broadcast burn.



Coastal Douglas-fir

Seedlot D47 (Fdc7): At the time of report submission, the exact origins of this seedlot remain unknown (listed as “Arizona” fir) but further digging through old research records may yet provide a more precise location. As such, the survey information has been included. This site is located in the CWHws1 and was planted at an elevation of 290m in 1960 with 2+0 bare root stock. Licensees intentionally destroyed most of the trees associated with this seedlot because of fears that it would promote the spread of *Adelges cooleyi* (although there was no evidence of it during the survey). Conclusions about survival cannot be drawn because of this. No other forest health issues were apparent on the remaining Douglas-fir at this location. Site quality was good (site series /04) so brush was potentially a significant factor in early stand development. Average height growth of co-dominant Fdc trees was 21.0m and average DBH was 42.2cm at an average breast height age of 33 years. The surviving Douglas-fir from this seedlot are out-performing the native hemlock, cedar, and amabilis fir growing at this location.



Good growth on surviving coastal Douglas-fir at site Fdc7.

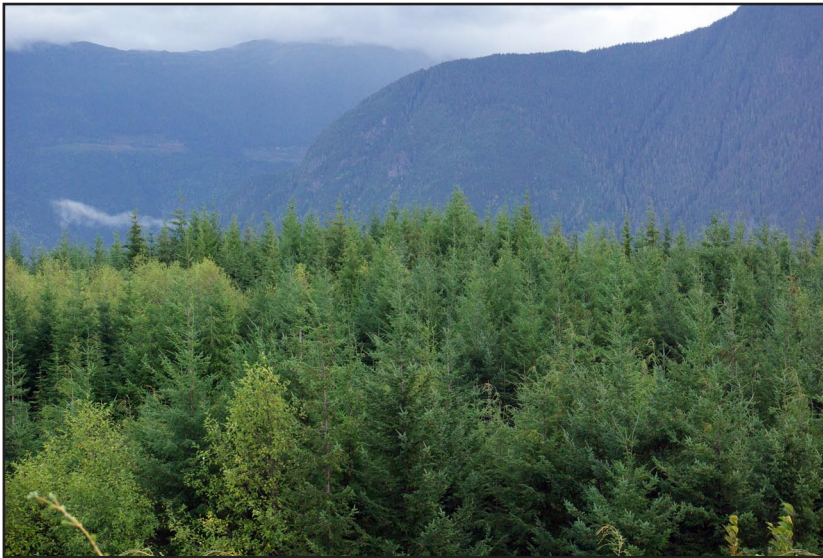
Seedlot 3868 (Fdc10): This site is located in the CWHws1 and was planted at an elevation of 230m in 1982 with 1+0 plug stock. The location was a dry lichen site with poor productivity (site series /02) and many trees were chlorotic. The area had been broadcast burned prior to planting which likely exacerbated the dry site conditions. Site quality was likely a significant factor in terms of survival and growth. Forking was common on many stems although most trees have recovered. Height growth was quite variable with co-dominant trees attaining a height of 11 to 15m at a breast height age of 15 to 22 years. Despite the harsh site conditions, the Douglas-fir from this seedlot were doing as well as native species occurring at this location.



Coastal Douglas-fir growing on a very harsh site in the CWHws1. Growth is quite variable but healthy trees are doing as well as local species.

Seedlot 3869 (Fdc13): This site is also in the CWHws1 along the Wedeene River near Kitimat, and was planted at an elevation of 350m in 1982 with 2+0 bareroot stock. The site is located on steep slopes that regularly experience some of the highest snowfall events in BC. Every tree in the plot, regardless of species, had a “pistol butt” stem form. Site quality was medium (site series /01) with a warm aspect and no cold air ponding. Although the history records show that 4,450 Douglas fir were planted, only a limited number could be found, likely indicating a high rate of mortality. On the surviving stems, there was a moderately high incidence of broken tops and forking. Current total stand density is about 1200 sph and natural Hw regeneration was often larger and taller than the Douglas-fir. There are other plantations of this seedlot in the Wedeene Valley but they are currently inaccessible due to road deactivation and washouts.

Seedlot 7402 (1031048-37): This site is also located in the CWHws1 at an elevation of 290m and was planted in 1987 with 2+0 bareroot stock. Co-dominant trees averaged 16.0m tall and 23.3cm DBH at a breast height age of between 17 and 22 years. Forest health issues were not common and overall survival seemed good. Site quality was good (site series /04) and high stand density was not a significant adverse factor. In some areas of the plantation where there were abundant Hw naturals, the coastal Douglas fir survival was lower and diameter growth was poorer. Of the four coastal Douglas-fir seedlots in this study, this seedlot appeared to have the best survival, overall stem form, and growth. Height growth exceeds that of native hemlock and amabilis fir growing on good sites.



A very healthy stand of 23-year-old coastal Douglas-fir planted in the CWHws1.



Western Larch

Note: There is significant size variation in all the western larch plantations due to the use of natural seed collections where “selfing” and/or “related mating” of less common species is a regular occurrence (Barry Jaquish, pers. Comm., 2010). To provide a more realistic picture of species growth potential on different sites, only co-dominant trees were used in calculations of average growth rates.

Seedlot Montana (Lw1 and Lw2): Seedlot origin location information is limited for these two sites with only the general area (NW and W Montana) currently available. Both test sites are in the CWHws1 and were planted in 1967 and 1968, respectively, at about 150m in elevation. Site quality is good in both areas (site series /04) so brush may have played a role in some trees being slow to reach breast height. Top damage and forking is frequent in Lw1 but stocking levels are reasonable and co-dominant trees are large, averaging 28.0m tall and 39.0cm DBH at an average breast height age of 41 years. Top damage from snow loading is less frequent in Lw2 and the trees are growing equally as well. Co-dominant heights and diameters average 27.4m and 33.2cm, respectively, at an average breast height age of 39 years. Western larch growth rates from this seedlot are better than predicted for either western hemlock or amabilis fir on a good site and better than coastal or interior Douglas-fir on comparable sites. There does, however, appear to be a high risk of stem breakage from heavy snow loading.



Height growth of larch is as good or better than that predicted for local species (right), but top damage from snow (left) is a problem to be aware of on many sites.

Seedlot 2554 (Lw7, 8, 9, 10, and 093E098-19): Lw8 and Lw9 (640m and 1000m elev., respectively) are in the SBSdk transitional to mc2; Lw7 and Lw10 (1000-1100m elev.) are in the SBSmc2; and 093E098-19 is in the SBSdk (850m elev.). All sites were planted 1981 with 1+0 plug stock. There was evidence of spot or pile burning at Lw7 but not Lw8, and survival appeared better on these burned areas. The incidence of forest health factors in Lw8 was relatively low (2 instances of fork or sweep in 16 trees), however, within the Lw7 plantation there were pockets with nearly 50% top breakage or stem damage, most likely from frost or snow loading. In Lw9 there were areas in which nearly every tree had a dead top or fork, or both. Stocking levels at Lw8 were moderate to good but generally poor on Lw7, Lw9, and 093E098-19. Lw8 appears to be a bit of an anomaly as the growth rates on the site are significantly greater than on the other sites planted at the

same time and with the same seedlot. The average height and diameter in Lw8 was 20.3m and 23.8cm, respectively, with breast height ages ranging from 23 to 25 years. The trees in Lw7, Lw9, Lw10, and 093E098-19 all had much lower average heights and diameters of 10.5m and 15.0cm, respectively. The reason for the big differences is most likely related to site quality. Soils were shallow, very stony, and sometimes compacted at Lw7, 9, 10 and 093E098-19 (with a dry, south exposure on 9 and 10) but deeper with abundant seepage on Lw8 (site series /06) and a northwest aspect. Trees on Lw7 and 9 looked better when they were growing in moist microsites. This seedlot is growing as well as or better (in some cases much better) than the native species on similar sites and provides an excellent opportunity to increase species diversity and productivity in the SBS if established on appropriate sites. The use of class A orchard seed will reduce the size variability issue found in these natural seed plantations.



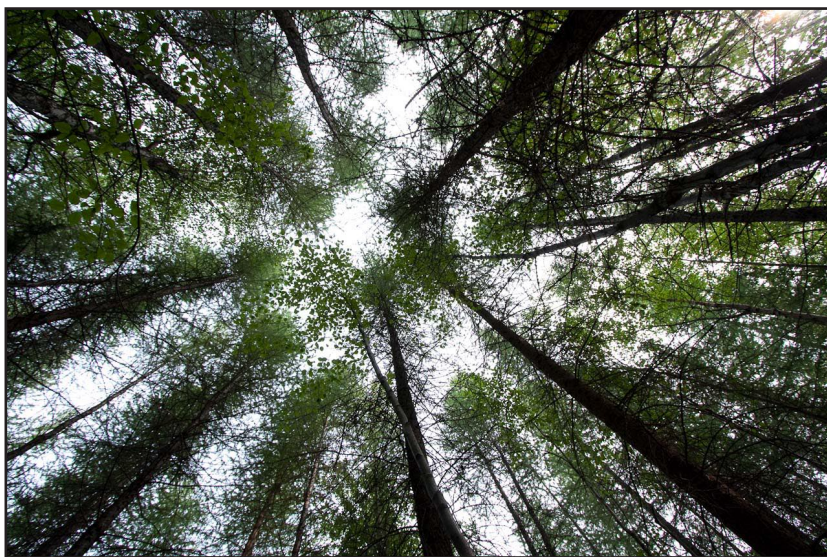
Site Lw7(1)



Site Lw9(b)



Site Lw7(2)



30-year-old western larch at site Lw8. Growth on this site is exceptional and significantly better than that predicted for the local spruce and pine.



Seedlot 2506 – Coastal Sites (Lw3, Lw4, Lw5, and 103I028-803b): These sites are all located in the CWHws1 (approximately 230 to 450m in elev.) and were planted in 1980 (1984 for 103I028-803b) with 1+0 PSB 313 stock. These plantations were all relatively small (1100 to 4000 trees) and established inside operational blocks of native species. Although it is not explicitly stated in the records, discussions with locals confirm that the larch plantations were all established as single species units. Current conditions indicate that overall survival was generally poor on these frequently steep, rocky, and poor to medium sites (site series /01 & /04). Site quality was better on Lw 4 but, despite having a similar silviculture regime to the other plantations (broadcast burning), it also had poor survival, possibly because of significant hemlock competition. As has been noted previously, there was substantial variation in larch height on these four sites. Co-dominant tree heights and diameters averaged 13.2m and 16.5cm, respectively with breast height ages around 22 years (note that 103I028-803b was 4 years younger). For the western larch that did survive, there is very little frost damage or stem breakage and there were no other major forest health issues. This seedlot is growing at a rate comparable to the native species on similar sites and seems to a viable potential addition to the species complement.



Dominant 30-year-old larch at site Lw5.



Co-dominant 26-year-old larch at site 103I028-803b.

Seedlot 2506 – Interior (Lw11 and Lw12): Both these sites were planted in 1982 with the same seedlot and 1+0 PSB 313 stock, but in different BEC Zones (ICHmc2 and SBSmc2, respectively). Elevation was 700m in Lw11 and 960m in Lw12. Lw11 is the only example of larch in the ICH in the project population although Barry Jaquish has established three trial plantations (Date Creek, Brown Bear, and Bell) that are growing at a very similar rate (B. Jaquish, Pers. Comm., 2011). Site quality was good in the ICH and SBS (site series /03 and /05, respectively) so brush competition was potentially a significant factor at both locations. Average height growth of the co-dominant larch was better at Lw11 than at Lw12 (13.2m versus 10.8m in Lw 12). Diameter growth was lower at the Lw11 site, most likely due to the effects of overhead competition. Average breast height diameters of the co-dominant larch at Lw11 and Lw12 were 13.1cm and 15.0cm, respectively. Survey comments from a 1984 walkthrough indicated that there were “no survivors” in Lw11 although the 2010 investigation did locate a number of healthy trees. This would indicate that initial survival was likely quite low. A similar walkthrough survey of Lw12 in 1983 indicated survival at “approximately 50%” but once again, many healthy trees were located in 2010. There was some evidence of frost damage in Lw12 but little current evidence of forest health issues in Lw11 except a needle disease on the lower 1/3 of some of the crowns.

Considerable variability in height growth was again common on these sites but those trees in the dominant or co-dominant crown position were generally as good as or better than what could be expected for native species. This seedlot shows good potential to grow in areas well outside its normal range and, provided there is adequate soil moisture and limited early brush competition, can meet or exceed the growth rates of local native species.



Co-dominant larch in a healthy mixed stand of spruce and pine at site Lw12 (above).

One of a limited number of surviving larch at site Lw11 (left).

Seedlot 5101 (93E100-96, 93K003-50, 93L048-32): All three sites were planted with the same seedlot but 93L048-32 was planted in 1981 and the other two were planted in 1992. 93E100-96 is in the SBSmc2 (1000m elev.) and the other two sites are in the SBSdk (750 to 800m elev.). Average height and diameter of co-dominant larch in the older plantation was 13.4m and 14.7cm, respectively, and 7.1m and 12.1cm in the two younger ones. 93K003-50 was generally classified as a medium site (site series /05) although there were areas of impeded drainage which lowers productivity. The other two sites were classified as good (site series /06). The original plantations were established as intimate mixtures and survival appears to have been reasonable on 93E100-96 and 93L048-32, despite relatively brushy conditions. Survival was generally poorer on the 93K003-50 site. The incidence of forest health factors was highest on 93K003-50 although frost and snow damage resulting in bud necrosis, forks, and sweep were relatively common at all three locations. Seedlot 5101 also has the potential to grow as well or better than native species would on good sites but again this would only be the case if it were established on better quality sites with appropriate silviculture treatments and the expectation that there will be substantial damage from frost and possibly snow loading.



Forking of the main stem was a common health factor with this seedlot.



19-year-old Lw at site 93K003-50.

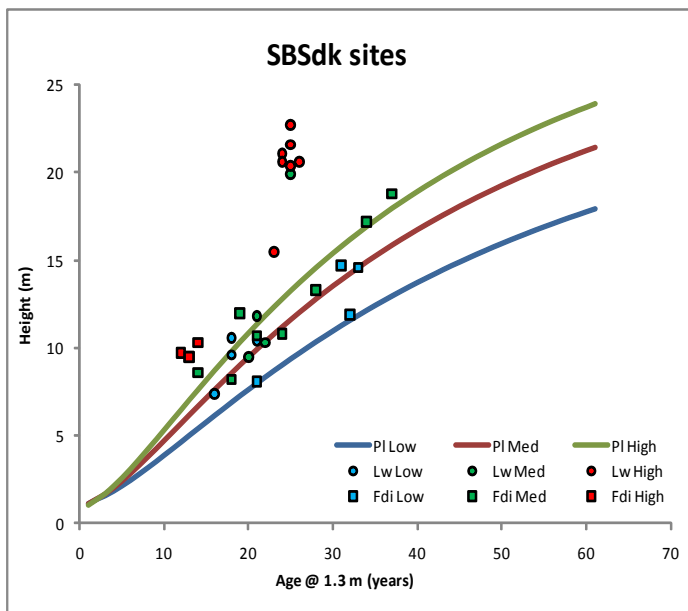
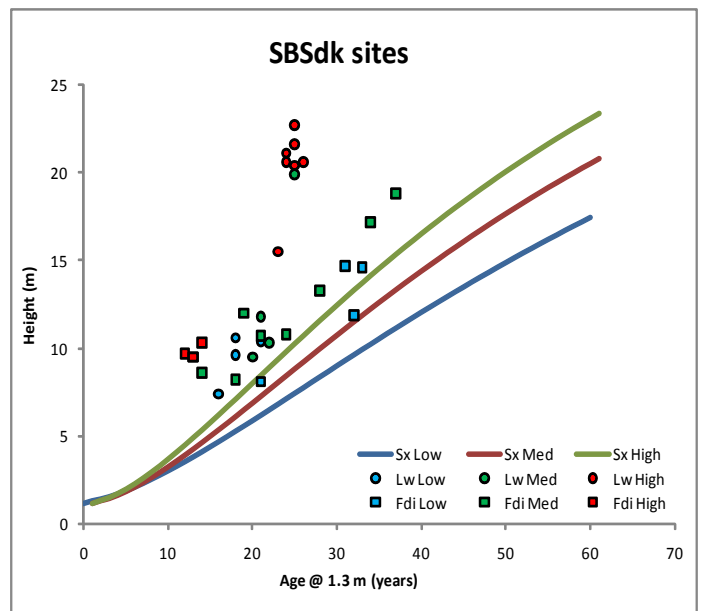


30-year-old Lw at site 93L048-32.

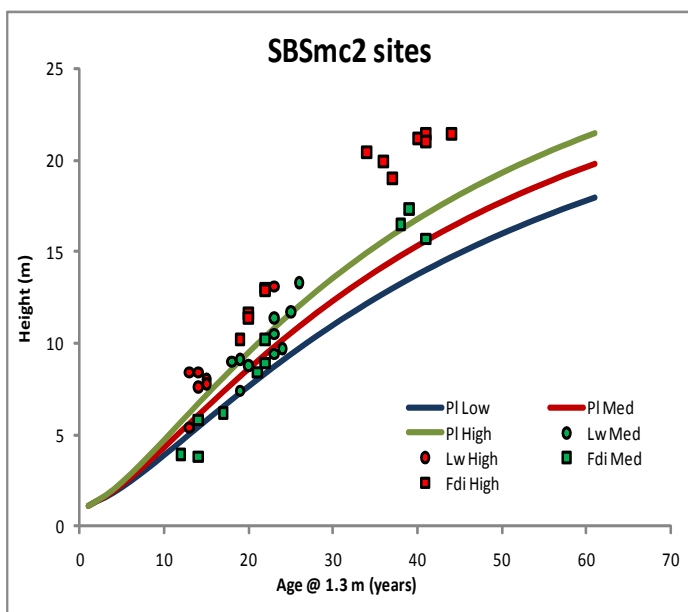
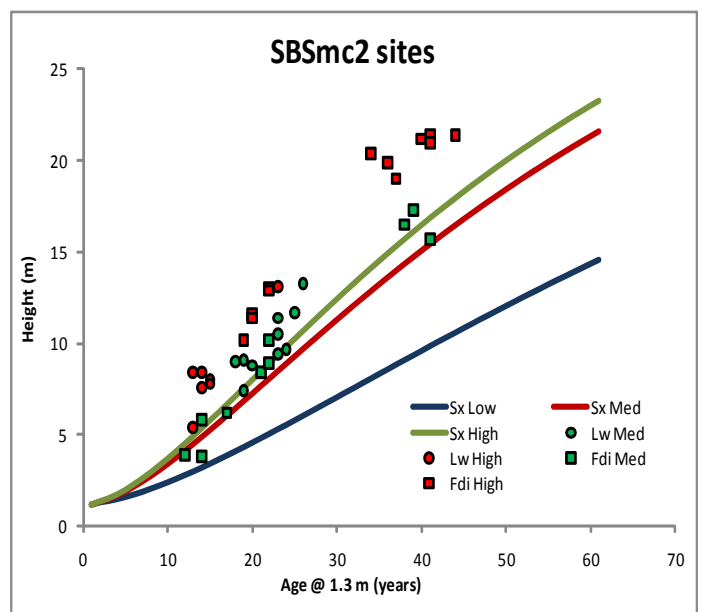
OFF-SITE GROWTH POTENTIAL

A preliminary examination of “growth potential” was carried out that examined the height growth of off-site trees that met the criteria for site tree selection as defined in the 2009 SIBEC Sampling and Data Standards: (<http://www.for.gov.bc.ca/hre/sibec/documents/standards.pdf>) at each plot (note that these were not always available). Height growth potential curves for the local native species were created by entering the most up-to-date SIBEC information for the plot site series into the BC Forest Service’s Site Tools program (Version 3.3, Province of BC, 2004). These site quality curves were then overlaid with the breast height age versus total height data points collected for the off-site species grouped by site quality (low (light blue), medium (green), and high (red)). Some examples of these figures are presented below by BEC zone/subzone. The full set of curves is included in the digital report submission as Microsoft Excel charts.

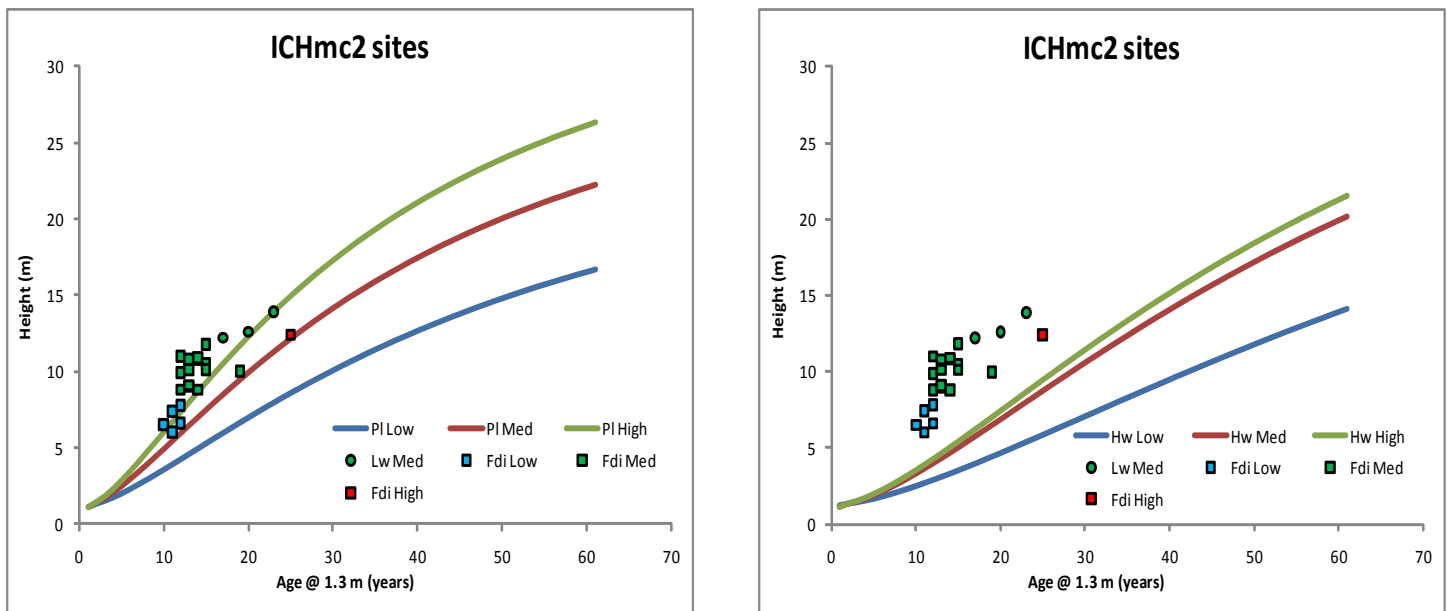
While a full interpretation of these results will be left to the researchers in the Genecology and Seed Transfer program, it is very interesting to note that in many instances, the current realized growth potential of healthy off-site trees is as good or better than that predicted for the local species. For example, in graph 1 below, the western larch and Douglas-fir growing on medium sites in the SBSdk are all on or above the predicted medium-site growth curve for lodgepole pine and above the predicted high-site growth curve for hybrid spruce. In some instances, the growth of the off-site species on high-sites was significantly better than that predicted for the local species (e.g. Douglas-fir in the SBSmc2 compared to both lodgepole pine and hybrid spruce - Graph 2). Similar results were found for the other subzones examined in this report.



Graph 1. Height versus breast height age of interior Douglas-fir and western larch in the SBSdk subzone compared to growth potential site curves of native lodgepole pine (left) and hybrid spruce (right).



Graph 2. Height versus breast height age of interior Douglas-fir and western larch in the SBSmc2 subzone compared to growth potential site curves of native lodgepole pine (left) and hybrid spruce (right).



Graph 3. Height versus breast height age of interior Douglas-fir and western larch in the ICHmc2 subzone compared to growth potential site curves of native lodgepole pine (left) and western hemlock (right).

SUMMARY

This operational off-site species plantation assessment project has clearly demonstrated that it is possible to successfully establish some of the tree species that are native to BC, well outside their current climatic range and allowable seed transfer zones. Field data for Douglas-fir and western larch plantations, some up to 50 years old, indicate that not only can these species survive in non-optimal climates, but also that they have the potential to grow at rates that are as good as or better than the local species. All the seedlots assessed in this project were from natural stand collections and grown in inferior conditions (relative to today's nursery standards), yet many have done surprisingly well with little or no silvicultural interventions to assist them. With improved nursery practices and class A seed available for both western larch and Douglas-fir, these two species show excellent potential within parts of the ICHmc2, SBSdk, dw3, mc2 and CWHws1. The use of both species may help mitigate the anticipated impacts of climate change on our forest resources.

As both western larch and Douglas-fir are still climatically off-site in the subzones examined in this report, appropriate site selection and silvicultural treatments are even more important to achieving successful plantation establishment than with local species. The field assessment of the operational plantations made it clear that early survival was critical to establishing a viable off-site species plantation. Although the same can be said for all planted species, the use of appropriate silvicultural treatments such as burning, prompt reforestation, proper stock type selection, and early vegetation control, have the potential to significantly improve the survival and growth of these off-site species. Although many of the individual seedlots examined in this study have expired, for those that performed well when planted outside their normal range, future collections from similar locations should have the same potential for growth in a range expansion program.

ESTIMATED SEEDLOT POTENTIAL FOR RANGE EXPANSION

BEC Unit		Fdc	Fdi	Lw
CWHws1	More Potential	402, D47	D32, D26	Montana
	Less Potential	3868, 3869		2506
ICHmc2	More Potential		8482, 8281, 1256, 8580	2506
	Less Potential			
SBSdk	More Potential	2554	781, 377, 14502	2506, 5101
	Less Potential		3821, 689, 114, 867, 2615, 2906	
SBSdw3	More Potential		14502	
	Less Potential		3821	
SBSmc2	More Potential		D32	
	Less Potential	2554	3821, D29, 114, 867, 2615, 2906, 1885	

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