Squamish Forest District

Extension Note

Extension Note 001

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Plantation Performance in the Coast–Interior Transition

By Jim Hunt

Abridged from:

Scagel, R.; L. Erikson; M. O'Neill; T. Perzoff; and B. Marshall. *Plantation Performance Normals in the Coast Interior Transition—Third Approximation.* 2001. Transition Zone Working Group, Squamish Forest District, BC Ministry of Forests. Squamish, BC. Internal document.

Download copies of this report from: www.for.gov.bc.ca/vancouvr/district/squamish/silviculture/silvstart.htm

INTRODUCTION

The Coast–Interior Transition in southwestern British Columbia is a narrow geographic area that lies between, and overlaps, two much-larger areas of the province traditionally known as the Coast and the Interior. The Coast–Interior Transition corresponds to the Submaritime Seed Planning Zone as described in the Forest Practices Code's *Seed and Vegetative Material Guidebook* (BCMoF and BCMoE 1995a). The area is characterized by many species of commercial trees and varieties of competing vegetation, a variable annual climate, and steep ecological gradients. Plantation management in the Coast–Interior Transition is considered difficult; in particular, low-elevation sites are plagued with repeated plantation failures. Concerns include: soil moisture, temperature, competing vegetation, stock quality, delayed planting, planting time, and site preparation (Scagel et al. 1992a, 1992b).

In 1997 the Transition Zone Working Group (TZWG)[1] initiated a study of plantation performance in the area. Free-growing survey data—supplemented by data from measurements of selected plantations—were gathered and analyzed. The study involved the creation of a plantation performance database containing information about stocking, growth, and vegetation; it is the largest such database in British Columbia. The database has led to the generation of a set of tree growth curves (or "normals") for the Coast–Interior Transition—i.e., a set of graphs that describe actual performance. Normals allow forest managers to quantitatively address the question "How well are our plantations doing?". Three versions of the growth curves have already been released.

This Extension Note summarizes a longer report about the study, prepared by Scagel et al. 2001,[2] which includes a complete set of the most recent growth curves.

OBJECTIVES

In an effort to learn more about plantation performance in the Coast–Interior Transition, some of the objectives of the project are:

- Quantify how plantations in the Coast–Interior Transition are performing relative to the guidelines in the Forest Practices Code's *Establishment to Free Growing Guidebook, Vancouver Forest Region, April 1995* (BCMoF and BCMoE 1995b).
- Quantify how plantations in the Coast–Interior Transition are performing relative to other, similar plantations.

METHODS

This report is concerned only with growth and stocking density. Data do not represent specific combinations of ecological or management conditions, rather they are a "snap shot" of stocking and growth across a broad range of Coast–Interior Transition sites and management practices. Unfortunately, due to the complex logistics of data collection, representation of richer, wetter sites is poor. The analysis was restricted to mainly zonal sites to facilitate comparisons.

Participating agencies submitted results from operational Free Growing Surveys conducted in

[1] The Transition Zone Working Group is a collective of representatives from government and industry, formed in 1990, to improve silviculture in the Coast-Interior Transition, exchange ideas and reports, and co-ordinate research trials and other co-operative efforts.

[2] Available at the BC Ministry of Forests' website.

Table 1. Description of surveyed area, by adminstrative era.

Administrative era	Harvesting years	Strata (no.)	Area (ha)	Plots (no.)	Trees (no.)
Forest Practices Code	1995-1999	129	1 315	1 419	2 896
Silviculture Regulation	1987-1994	400	5 781	2 874	9 119
Section 88	1962-1986	124	2 243	793	2 417
Total		653	9 339	5 086	14 432

96 drainages between 1997-2000 for 476 openings, totalling 653 strata. The surveyed areas represent 6% of the timber harvest landbase in Squamish Forest District. Approximately 70% of the area surveyed occurred in zonal ecosystems.

ECOLOGICAL AND GEOGRAPHICAL DISTRIBUTION OF SURVEYED OPENINGS

This Extension Note focuses on the Coast–Interior Transition, however, the analysis includes some other areas from the Coast in order to evaluate standards for the entire Squamish Forest District. Of the nine subzones/variants in the Squamish Forest District (Green and Klinka 1994), five biogeoclimatic subzones are present in the Coast–Interior Transition area:

- CWHds1 Southern variant, Dry Submaritime subzone, Coastal Western Hemlock zone.
- CWHms1 Southern variant, Moist Submaritime subzone, Coastal Western Hemlock zone.
- ESSFmw Moist Warm subzone, Englemann Spruce–Subalpine Fir zone.
- IDFww Wet Warm subzone, Interior Douglas-Fir zone.
- MHmm2 Leeward variant, Moist Maritime subzone, Mountain Hemlock zone.

HISTORY AND MANAGEMENT

The plantations included in the study were harvested between 1962 and 1999 **(Table 1)**. Twenty-four per cent of the openings were between 5 and 8 years old, i.e., the early and late ages for conducting most free-growing surveys. The age of blocks reflects the silviculture management strategies that were in effect at that time. Eighty percent of blocks pre-date the introduction of the Forest Practices Code in 1995 (Table 1) and may not be representative of later practices. Approximately 24% of the survey areas were backlog (i.e., harvested before 1987).

Site Preparation

In the Coast–Interior Transition, between 1973 and 1999, across all subzones, approximately 17% of the harvested areas received some form of site preparation. Site-preparation activities declined in 1990 because harvesting shifted to higher elevation sites with adequate planting spots and because smoke management constraints increased. Broadcast slash burning had accounted for over 80% of the site preparation and occurred mainly in the CWHms. Over 85% of the surveys were conducted on sites that had received no form of site preparation. Approximately 16% of the survey involved openings that had been slash burned.

Planting

Between 1973 and 1999, 84% of the harvested area was planted. These statistics only partially indicate the degree of multiple plantings. In the CWHds1 and IDFww at least 16% of the area has had multiple plantings. The actual planting densities are not available, but common densities are 1200 trees/ha which suggests that about 24 million seedlings have been planted over this period. It was not possible to determine species composition, survival, stock type, or seedlots. While 35% of the blocks were planted within one year after harvest, 92% were planted within three years after harvest. Recent plantings usually have regeneration delays of less than one year. Eighteen strata had been left entirely to natural regeneration. A total of 14 423 trees were sampled over 140 combinations of subzones, site series, and species. The species distribution reflects the bias of sampling zonal sites. Over all subzones, 56% of surveyed trees were planted. In the MHmm1 and CWHvm, the majority of measured trees were natural or advanced regeneration. However, growth results are restricted to planted seedlings where the aging was unambiguous. The analysis of growth trends of natural and advanced regeneration is beyond the scope of this study.

Vegetation Management

In the Coast–Interior Transition, across all subzones, nearly 25% of the area has received some form of vegetation management. Sixty per cent of the brushing took place within three years after planting. Timing of vegetation management was not consistent in any subzone/variant. The amount of brushing was highest in the IDFww and CWHds1 and lowest in the MHmm. The large amount of brushing in the IDFww likely reflects multiple brushings. Eighty per cent of the surveys were conducted on sites that had no vegetation management. Nearly 75% of the survey area in the IDFww and 62% of the area in the CWHds1 were brushed at least once.

MEASUREMENTS

Growth

In 1997 and 1998, the target was to measure one median size sample tree per plot[3] for species, age, total height, leader increment, and ground-level diameter. In 1998, additional height increments were collected for determinate species. There is a concern that trees larger than median size were sampled, thus overestimating the performance of plantations.

In 1999, two trees per plot were measured: the tree closest to

[3] In practice, the goal of one sample tree per plot was rarely achieved.

Table 2. Summary of density and stocking statistics by subzone and for zonal site series.

Biogeoclimatic subzone/ variant	Site series	FPC Guidebook standards: Min. required (no. stems/ha)	FPC Guidebook standards: Target (no. stems/ha)	Surveyed: Strata (no.)	Surveyed: Area (no.)	Surveyed: Plots (no.)	Density and stocking: Total conifers (no. stems/ha)	Total well-spaced (no. stems/ha)	Max. well-spaced [a] (no. stems/ha)	Total well-spaced free growing (no. stems/ha)	Max. well-spaced free growing [a] (no. stems/ha)
CWHdm	01	500	900	6	65	99	4454±5843	1115±338	819±86	767±117	556±558
CWHds1	01	500	900	88	1179	685	1993±1010	780±194	747±129	621±183	399±405
CWHms1	01	500	900	249	4217	1768	2856±1700	891±202	782±98	619±189	610±251
CWHvm1	01	500	900	2	29	35	4025±148	791±44	647±19	250	50
CWHvm2	01	500	900	14	210	178	3884±1791	947±149	792±75	797±270	636±303
ESSFmw	01	700	1200	20	157	177	3873±2649	951±310	820±298	532±291	387±331
IDFww	01	400	900	33	303	183	1856±1047	839±252	540±93	707±233	465±129
MHmm1	01	500	900	10	216	148	4212±1550	936±154	778±125	836±84	697±120
MHmm2	01	500	900	33	748	205	3023±1067	1050±102	826±51	848±215	728±97
Total							3346±1867	992±200	750±108	615±288	552±184

[a] Using M-value.

the plot center, and the tallest tree in the plot. In 2000, to improve the sample size and statistical comparisons, two additional trees were sampled between the regeneration plots.

Retrospective surveys from 1993 and 1994, were also included where 25–30 trees/strata were measured. In all the surveys, the following tree characteristics were measured: total height, height to base of current increment, height to base of second increment, and diameter. However, for indeterminate species, only the total height and the most recent increment were measured.

Stocking

Stocking estimates were completed on 5086 plots. The stocking survey includes estimates of total conifer stocking, well-spaced stocking, and well-spaced free-growing stocking. The free-growing criterion is based on the minimum stocking height being 150% of the height of surrounding vegetation, and does not consider the minimum heights in the *Establishment Guidebook* (BCMoF and BCMoE 1995b). Prior to 1999, estimates of well-spaced and free-growing conifers were based on discounting survey results by the appropriate M-value (BCMoF and BCMoE 1995c). In 1999 and 2000, both M-value and non-M-value estimates were included in most surveys.

Sample Size

Distributions of sample tree species and ages were quite variable; 4249 of the sampled 6968 height increments were Douglas-fir. Scagel et al. (1985) provides a sampling technique that balances intensity and extensivity. A sample size of 20–25 trees/survey strata is adequate to provide a stable estimate of the mean for different growth variables and to minimize the standard deviation of the mean. An acceptable sample size for determining a zonal growth normal is based upon surveys of 20 strata equally distributed across 15 years of plantation establishment.

RESULTS AND DISCUSSION

The results are restricted to describing the performance of planted seedlings on zonal sites (site series 01).

Density and Stocking

The density and stocking estimates for zonal site series in the nine biogeoclimatic zones represented in the Squamish Forest District are presented in **Table 2**. Pooled across all biogeoclimatic zones, the average total conifer stocking is approximately 3300 trees/ha, more than double the planting density of 1200 trees/ha. Average total conifer density ranges from a low of 1800 trees/ha in the IDFww and 1990 trees/ha in the CWHds1, to a high of 4500 in the CWHdm. Without considering stem distribution, the total density would be adequate to satisfy the stocking requirements.

The average well-spaced stocking is 750 trees/ha—only 22% of the average total density. The average well-spaced free-growing stocking is 74% of the well-spaced stocking. The use of the M-value reduces the total well-spaced trees/ha by 25%, and the well-spaced free-growing trees/ha by 10%.[4]

[4] Over the entire survey, the discrepancy between M-value and non-M-value estimates of well-spaced stocking increases as stocking density increases. On average, non-M-value estimates of stocking are reduced by about 32% for well-spaced stocking and 52% for free growing by the imposition of an M-value. The imposition of the M-value is not sufficient to account for the difference between planted density and well-spaced stocking. Nor does the imposition of M-value artificially prevent the target stocking from being reached.

The total well-spaced stocking exceeds the target stocking in four ecosystem classifications: CWHdm, CWHvm2, MHmm1, and MHmm2. In the CWHds1 and ESSFmw, the average maximum-well-spaced free-growing stocking does not quite meet the minimum stocking requirement. Even in ecosystem classifications with a large sample size, the variability in stocking estimates is 25% as large as the mean. This variability requires further examination.

The loss of more than 70% of the total number of trees from the survey due entirely to spatial distribution also warrants examination. The explanation could be biological, i.e., due to the patchy nature of natural regeneration. However, the survey technique itself may be at fault due to the application of M-values, and/or fundamental issues concerning accuracy, precision, and repeatability of survey results.

Another troubling feature of this result concerns the possibility of large-scale plantation mortality being masked by ingress of naturals. Assuming an average planting density of 1200 seedlings/ha, the average well-spaced stocking suggests that there may be as much as a 37% mortality of planted trees. Add to this that 40% of the regeneration is composed of natural regeneration and the mortality could be even higher. Although biological explanations should be considered, the possibility of serious failure of the survey procedure should also be considered.

Although average well-spaced stocking is only 30% of the total conifer stocking, it is nearly 80% of the target stocking, not considering free-growing criteria. This indicates that minimum stocking was easily achieved on all sites and therefore sites were being managed according to targets.

Compared to the results for well-spaced stocking, sites varied considerably in their ability to achieve free-growing stocking standards. Generally, the proportion of free-growing stems was considerably less than the well-spaced stems. Part of this lack of achievement is also due to the use of M-values. This failure to achieve free growing may be due to inadequate height and/or to competing vegetation. Although these strata currently have not passed the minimum standards, it is expected that they will continue to grow into acceptable stocking—they should not be considered failures.

It is possible, given the early age of some of these plantations, survey methods, and the use of M-values, that the levels of free-growing status will improve over the next few years. However, that 20% of the strata failed to achieve free-growing status **(Table 3)**, and the subsequent effect of delaying projected harvests warrants examination. It is also noteworthy that only 35% of the surveyed area achieved 80% of the target stocking.

Growth Curves

Growth curves were generated for each of the 20 different combinations of species on zonal ecosystems where sample sizes were adequate (as shown in **Table 4**). One example from the set of growth curves (or "normals") for Douglas-fir is shown in **Figure 1**. Examples of how to interpret the graphs are shown in Figures 2–4. Note that age refers to the age of the tree regardless of the period since harvest commencement, and the early and late free-growing periods referred to in Table 4 and Figures 1 and 2 are early and late free growing minus regeneration delay. Table 4 compares the minimum height requirement specified by the *Establishment to Free Growing Guidebook* (BCMoF and BCMoE 1995b), with mean heights at early and late free growing. In addition, the proportions of trees that exceed the minimum heights at early free growing are indicated. On average, growth exceeded the minimum

Table 3. Classification of free-growing status, by subzone.

Biogeoclimatic subzone/variant	Fail (no. sites)	Acceptable (no. sites)	Desirable (80% of target) (no. sites)	Total (no. sites)
CWHdm	8	5	24	36
CWHds1				905
CWHms1	583	1411	1043	3038
CWHvm1	15			15
CWHvm2	52		131	1184
ESSFmw	40	21		61
IDFww	70	110	109	289
MHmm1	33	122	65	220
MHmm2	9	81	25	115
Total				
(ha)	990	2151	1722	4862
(%)	20%	44%	35%	

Table 4. Actual height growth relative to minimum heights specified by the *Establishment to Free Growing Guidebook* (BCMoF and BCMoE 1995a). Site Series 01 only .

Biogeoclimatic subzone/ variant	Tree species	Height increments [a] (no.)	FPC Guidebook min. height (cm)	Early free growing / regeneration delay [b] Years after planting (no.)	Early free growing / regeneration delay [b] Mean height (cm)	Early free growing / regeneration delay [b] % >min. height (%)	Late free growing / regeneration delay Years after harvesting (no.)	Late free growing / regeneration delay Mean height (cm)
CWHdm	Fd	236	300	5	153	0	8	387
CWHds1	Fd	2156	225	5	172	18	8	261
	Py	1001	125	5	155	51	8	262
	Lw	910	125	5	153	63	8	289
	Cw	188	150	5	153	60	8	271
	Sx	172	100	5	78	17	8	
CWH ms1	Fd	4161	225	5	130	5	8	238
	Sx	3393	100	5	84	34	8	142
	Cw	702	150	5	119	32	8	241
	Yc	331	150	5	93	17	8	176
	Lw	141	150	5	74	0	8	
	Ba	127	75	5	111	81	8	155
CWHvm2	Ba	68	175	5	89	0	8	
ESSFmw	Sx	1130	100	8	100	53	16	
IDFww	Fd	1468	150	5	245	39	11	
	Py	938	150	5	261	63	11	
	Lw	473	150	5	346	24	11	
MHmm2	Sx	1285	100	8	96	90	16	150
	Ba	262	60	8	97	100	16	195
	Yc	169	100	8	101	100	16	262

[a] Increments = number of increments involved in the calculation of height at age five years.
[b] Highlighted cells indicate where the average height exceeds the minimum height at early free-growing age.

requirement by the late free-growing period; however, half of the species/site combinations did not exceed the minimum height requirements by the early free-growing period (Table 4). This is an unexpectedly small number, and could reflect poor growth, or, possibly, that the minimum height requirements are not appropriate. The minimum heights in the *Establishment to Free Growing Guidebook* were set in expectation that 80% of the trees would exceed it by the early free-growing age;[5] in this survey, only 45% of all trees measured exceeded the specified minimum heights for early free growing, and only four combinations of species and subzones actually met the minimum height criteria.

In two instances—Douglas-fir in the CWHdm and amabilis fir in the CWHvm2—none of the measured trees exceeded the minimum heights; even the maximum heights achieved by these species fail to meet the minimum height criteria. The cumulative frequency distribution diagrams for each species (e.g., Figure 1) indicate the disparity between measured tree heights and the heights specified in the *Establishment to Free Growing Guidebook*.

Average height growth varies considerably between subzones. For Douglas-fir, the average height at age 5 years varies from 130 cm in the CWHms1 to 245 cm in the IDFww. Variation in height was expected among subzones, but it is surprising that the

[5] R. Scagel, Prinicpal, Pacific Phytometric Consultants, White Rock, BC; personal communication, November 2001.

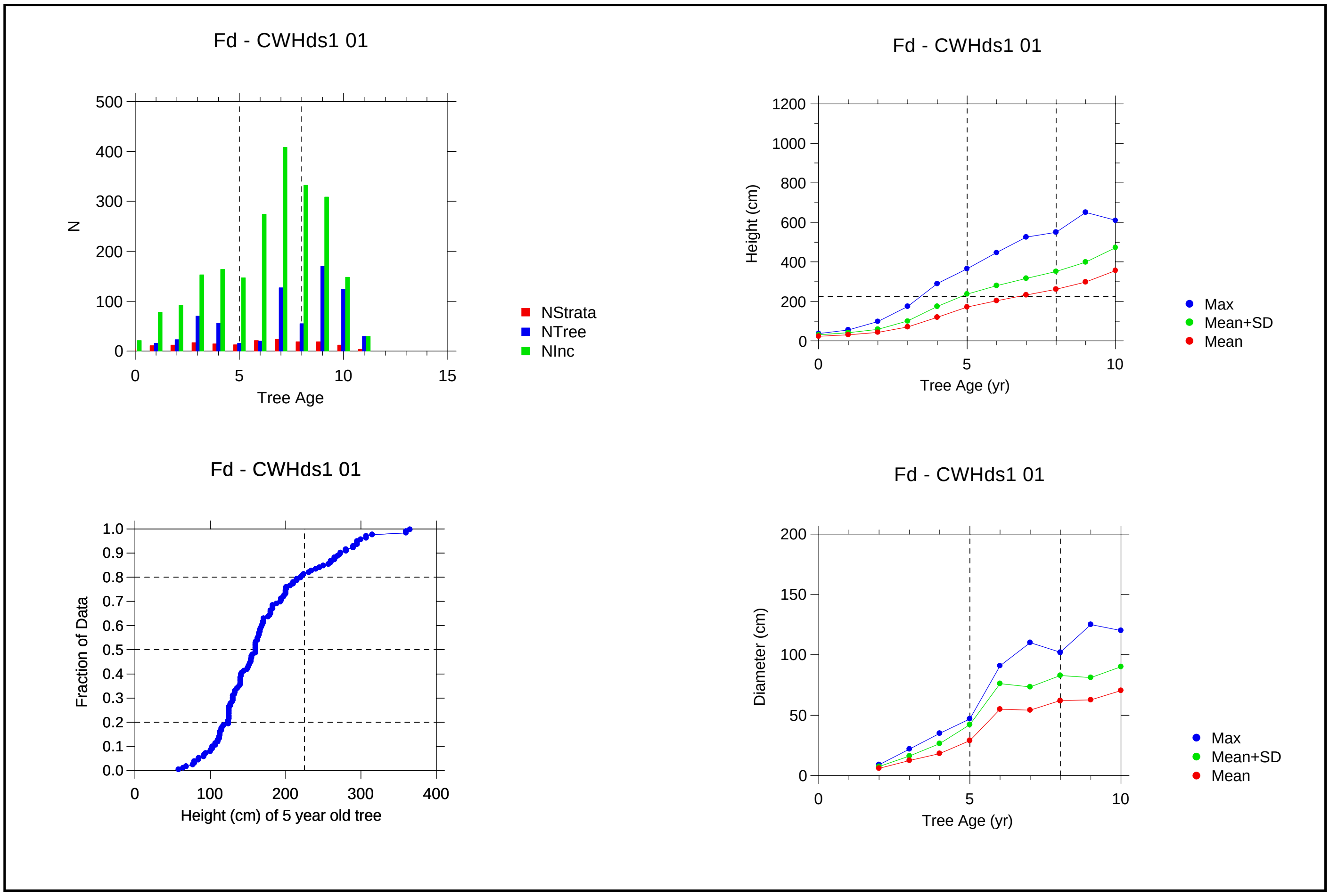

Figure 1. Growth normals for Douglas-fir in the CWHds1 [01].

best growth occurs in a severe subzone. This suggests that height growth in other subzones may not be realizing the site potential.

Tree measurements were not uniformly distributed with age. Growth curves refer only to stems with ≤10 years of growth because the sample sizes of older stems are not statistically stable.

Planting check, which occurred repeatedly in the first two or three years after planting, was a major factor in the failure of stems to achieve minimum height requirements.

How to Read the Growth Curves. Each set of growth curves reports a maximum height for each age and an average height for each age, and shows the standard deviations around the mean. The presentation defines the potential, expected, and variability of growth. The trend lines give an indication of growth projection.

An example of a growth curve appears in the figure below **(Figure 2)**. The growth curve reveals several issues about the performance of western redcedar in the CWHms1 01:

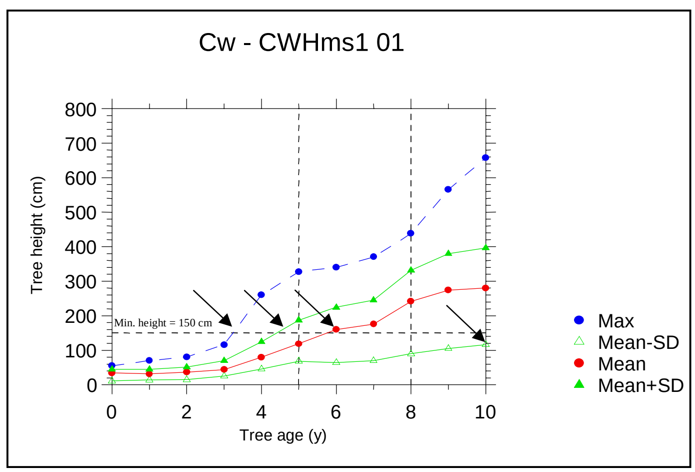

Figure 2. Example of a height growth curve for western redcedar in the CWHms1 [01].

• Mean (red line with solid circles): Western redcedar on a mesic ecosystem in the CWHms is not expected to achieve a minimum height of 150 cm until Year 6.

• Mean+SD (green line with solid triangles): Trees in the upper 80th percentile of the population are expected to achieve minimum height sometime between Year 4 and 5.

• Potential growth (blue line with solid circles): Indicates that exceptional trees can achieve minimum heights by Year 3 or 4.

• Mean–SD (green line with empty triangles): The lowest 20th percentile of western redcedar trees fail to achieve 150 cm by Year 10.

• A 6-year-old plantation with an average height of 225 cm would be considered a desirable result because it is in the top quartile of the normal.

• A 7-year-old plantation with an average height of about 180 cm would be about average for growth in the subzone.

• A 4-year-old plantation with an average height of 50 cm is well below the average for the subzone and is unlikely to achieve minimum heights by the late free-growing age.

Evaluating Plantation Performance Using Normals (Growth Curves)

The normals can be used as benchmark growth curves for evaluating plantation performance. Two examples within the same subzone and site series are shown below. Height samples were collected from 30 well-spaced trees per plantation at age 6 years with increments for the last two years (ages 4 and 5 years). This data was plotted against the normals curves (mean, upper and lower standard deviations) for comparison. The Smith Creek site has a sample mean height that is very close to the normals mean for ages 4–6 years, suggesting acceptable plantation performance **(Figure 3)**. The Gravel Creek site shows sample mean heights that correspond to the lower standard deviation, suggesting poor plantation performance **(Figure 4)**. Graphically projecting the data for ages 4–6 years at Gravel Creek indicates the plantation would meet the late free-growing standard of 225 cm at year 11 (add regeneration delay to obtain time from harvest). However, the plantation is not likely meeting its growth potential. The difference in performance between the two plantations may be attributed to an aerial application of Vision at age 2 years at Smith Creek, while Gravel Creek was untreated.

The normals may be used as a yardstick to assign acceptable or unsatisfactory performance ratings for plantations (e.g., Vyse 1981), or for ranking risk. Such benchmark comparisons may be helpful in the decision making process for herbicide application required within the Pest Management Plans. Spreadsheets and charts of the normals will be available from

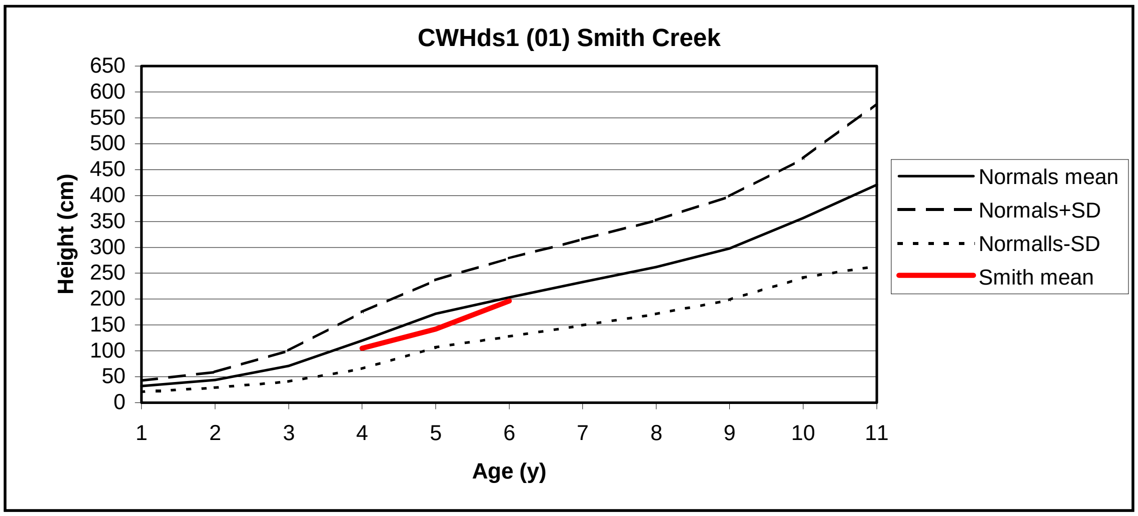

Figure 3. Smith Creek mean height of Douglas-fir plotted against normals mean and standard deviation.

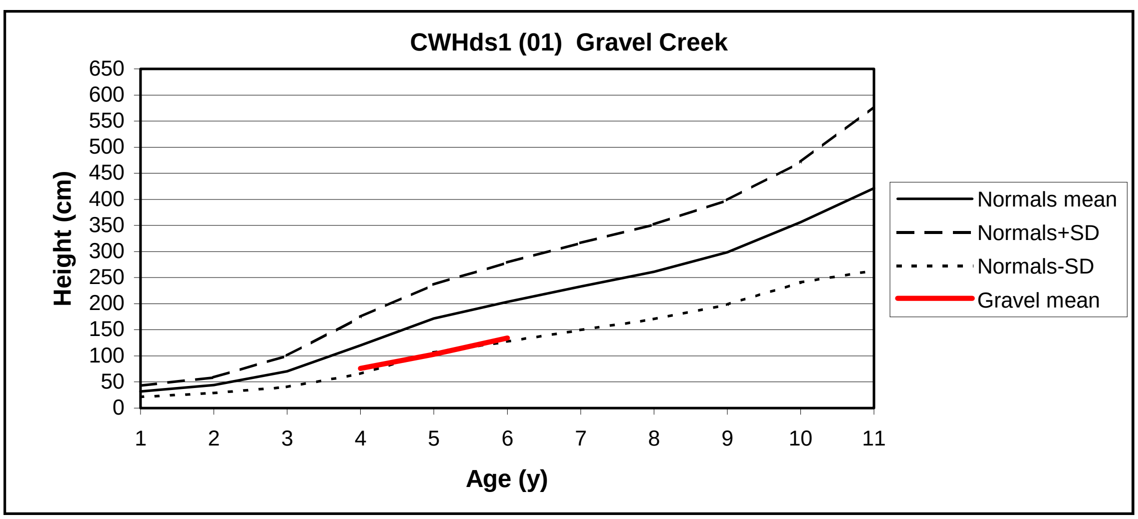

Figure 4. Gravel Creek mean height of Douglas-fir plotted against normals mean and standard deviation.

the Squamish Forest District website (http://www.for.gov.bc.ca/vancouvr/district/squamish/silviculture) to facilitate simple comparisons such as Smith Creek and Gravel Creek.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions about the study are summarized below, and recommendations are presented concerning the need for more data, new analyses, improvement in survey technique, and the possible effects of these results on forest management plans.

Survival and Stocking

The amount of replanting, the proportion of natural regeneration, the 70% discounting of total conifers in estimating well-spaced stems, and the difference between planting density and the well-spaced estimates, suggests that there is substantial mortality. Determining the true magnitude of the problem, the trend, and the reasons for such mortality are crucial to improving the reforestation success in the Coast–Interior Transition.

The potential magnitude of mortality is not a situation restricted to the Coast–Interior Transition and is comparable to results in Northern BC, Alberta, and Saskatchewan.[6]

» Assuming that planting density was 1200 seedlings/ha, the well-spaced stocking (750 stems/ha average) suggests that there has been at least 37% mortality; however, its cause and true extent remain unknown, and an explanation is required. This estimate of mortality may be conservative due to ingress of naturals. The **survival** estimate is probably biased by failure to incorporate seedling condition into the estimate.

» On average, well-spaced stocking was 70% less than total conifer density. Although ingress of natural regeneration contributes to this excess and mortality may contribute to the difference, it is also possible that the **sampling** design and accuracy of the free-growing surveys could have caused serious discrepancies.

» On average, there is a 20% difference between well-spaced and free-growing stocking. This suggests 20% of the surveyed well-spaced trees are discounted from the survey because of either growth, vegetation, and/or stem defect or pathology. Specific surveys need to be undertaken in order to determine whether the failure to achieve free-growing status is based on **height and/or vegetation**.

» The large variability in stocking estimates is a concern. Such variation may be due to local distribution patchiness or profound opening-to-opening variation in stocking. Further characterization of this **stocking variability** is required and should focus on planting delay and block age. It is suggested that the high variability may be related to historical variation in stocking, with older blocks having poorer stocking than more recent openings.

» The free-growing survey methodology uses the **M-value**, which substantially discounts the true stocking levels. Rather than imposing an M-value, it would be more appropriate to examine the stocking survey and determining the patchiness and distribution of stocking. If only 35% of the surveyed area is achieving 80% of target stocking, the effects on the Allowable Annual Cut need to be examined.

» The sensitivity of stocking estimates to different forest **management strategies** needs to be examined. In particular, the following comparisons should be undertaken as the database expands: early-to-late free-growing surveys, site preparation, planting delay, brushing, and plantations versus natural regeneration.

Growth

In interpreting the growth data it must be remembered that these results reflect some bias due to aging and sample selection issues. The appearance of a two-to-three-year planting check and the failure to meet the minimum heights by the early free-growing date suggest that either the growth potential is not being realized and/or the standards are inappropriate, or a combination.

» The frequency distribution graphs indicate that few species actually satisfy the criteria in the *Establishment to Free Growing Guidebook*, and even the maximum heights barely exceed the standards. It would be prudent to commission a specific survey to be used in revising the growth curves so that they could then be used to review the **minimum height standards**.

» The surveyed **maximum heights** indicate that growth potential is much greater than minimum heights in the *Establishment to Free Growing Guidebook*. Capitalizing on at least some of this potential will require that forest managers understand the conditions under which this growth occurs; additional surveys in "plus" plantations should be commissioned.

» **Planting check** is a frequent problem for all species on all sites in all subzones. The degree of, and reasons for, its occurrence need to be determined.

» Over 40% of the tree-growth information remains unanalyzed because it was collected on **natural regeneration**. These data were excluded because of ambiguities in aging the trees and failure to discriminate advanced regeneration from natural regeneration ingress after harvest. Growth normals for natural regeneration can be produced only on an opening-specific basis and as a contrast to planted seedlings.

» The sensitivity of growth estimates to different forest **management strategies** needs to be examined. In particular, the following comparisons should be undertaken as the database expands: site preparation, planting delay, brushing, and plantations versus natural regeneration.

Additional Data

The database is sufficiently developed that it is worth considering undertaking specific surveys to address some of the issues identified above. More data on tree growth are required; however, the present survey approach is not efficient. It is recommended that future survey work not be piggy-backed onto the Free Growing Surveys; but conducted as a stand-alone Regeneration Performance Assessment that is focused on target site series and management practices.

The **proportion of subzones** sampled is very large compared to other sets of statistics such as the Staked Survival Survey (SSS) and Regeneration Performance Assessment (RPA). In terms of area harvested, the MHmm1 and CWHms1 are well represented; however, more sampling is required in the other subzones. It is proposed that representative sampling consist of a minimum of 20% of the harvest area in each subzone. It is also recommended that the database be expanded to include adjacent Coastal biogeoclimatic subzones.

[6] See Footnote 5.

» Zonal **site series** have been well sampled but greater survey effort needs to be spent in the richer, wetter site series. These ecosystems with higher productivity and timber values are where intensive forest management is most likely to be conducted and where information about performance standards is critical to the decision-making process.

» The free-growing period is well represented, but there is insufficient height increment information to adequately develop early height growth curves. A reconstructive survey of young plantations would identify the magnitude of planting check. In particular, diameter-age relationships could be improved by adopting a destructive sampling technique. In addition to the younger age classes, extending the survey to an **age/size** that would permit entry into the height-intercept SI estimation tables will aid in evaluating plantation management techniques.

» While it is necessary to make the sample representative of the ecological variation in the Transition, it is also necessary to make the sampling representative of the different **silviculture activities**. An analysis of MLSIS needs to be conducted to determine the extent and degree of silviculture activities (e.g., stock type, planting season).

» The growth curves are constrained by the historical aspects of the annual cut in the Squamish Forest District. Over the years the **proportion of harvest** has gradually moved to higher elevations and to subzones that are more "Interior" in character. Additional data-collection effort should aim to represent Forest Development Plan areas.

» Given sufficiently well developed growth normals and some marginal costs, it is possible to develop **cost analyses**, develop risk assessments, and determine cost effectiveness of silviculture activities. Marginal costs should be extracted from MLSIS and analyzed to determine the nature of silviculture expenditures in anticipation of conducting a formal cost analysis.

» The present data analysis has focused on establishing robust height curves. As the database continues to expand it will be possible to produce **other curves**, e.g., diameter, height:diameter ratio, volume normals, as well as descriptions of competing vegetation.

» Additional survey and database issues arising from the compilation of the database are reviewed in Scagel et al. (2001).

Ecological, Climatic, and Historical Context

For all issues there is a need to develop a single source of information on the ecology and climatic conditions of the Coast–Interior Transition. Accompanying this should be an historical review of forest management, silvicultural activities, and achievements. This information is vital to determining the representation of any sampling and to explaining the results. Detailed zonal and yearly breakdowns are needed.

Effects On Forest Management Plans

Timber Supply Analyses and other forest management plans are based on various assumptions concerning growth and stocking. The sensitivity of these various models and plans is unknown. For instance, if the stocking and growth results are less than those assumed by the Timber Supply Analysis, then Allowable Annual Cut calculations may be too aggressive. Accurate modelling scenarios need to be developed.

Review of Standards in the Forest Practices Code Guidebook

In 1994, the height growth standards in the *Establishment to Free Growing Guidebook* were rationalized on an ad hoc basis with little supporting data.[7] It was recommended that these concepts be reviewed and specific surveys be undertaken to fill in these data and conceptual gaps. To date, a formal review has not been undertaken to address the inadequacies that were known at the inception of the Forest Practices Code.

As more plantations are surveyed using the Forest Practices Code standards, challenges to these standards and exemptions will occur. Scagel et al. (2001) have provided a general rationalization for the erection of standards and definitions that could be used as the basis for a review of the FPC standards. Two key issues require clarification: definition of minimum acceptable risk, and statement of plantation management standards.

SUMMARY

In 1997 the Transition Zone Working Group commenced a study of plantation performance in the Coast–Interior Transition in southwestern British Columbia. The intent was to quantify the performance of plantations in the Coast–Interior Transition relative to the Forest Practices Code's *Establishment to Free Growing Guidebook, Vancouver Forest Region* (BCMoF and BCMoE 1995b), and relative to other similar plantations.

A database was compiled from free-growing surveys covering 476 openings in nine biogeoclimatic zones. Data from 14000 trees, encompassing 14 tree species from areas harvested between 1962 and 1999 were analyzed. The report details the supporting database and the logic used for determining normals and setting standards. The outcome of the study is a set of benchmark growth curves. Ten height and diameter growth normals are presented for Douglas-fir, western redcedar, and hybrid white spruce for zonal site series. Some conclusions are presented concerning stocking on a subzone basis.

The average total conifer density reported was about 3300 trees/ha—more than double the planting density of 1200 trees/ha. Of these, an average of 750 trees/ha were well spaced—a discounting of 70% from the total conifers. An average of only 552 trees/ha were considered well-spaced free growing, an additional discounting of 20%. On an area basis, only 35% of the surveyed blocks achieved free-growing stocking status of 80% of target stocking. Only 45% of the trees measured at early free growing exceeded the minimum height requirements specified by the FPC Establishment Guidebook. For all species there appears to be a planting check for the first two to three years following planting.

This Extension Note also presents quite a number of recommendations concerning the need for more data, new analyses, improvement in survey techniques, and management considerations.

This Extension Note summarizes a longer report about the study, prepared by Scagel et al. 2001, which includes a complete set of the most recent growth curves; the growth curves will continue to evolve as the database becomes increasingly refined.

[7] See Footnote 5.

KEYWORDS

Plantation performance, growth curves, seedling survival, stocking density, tree diameter growth, tree height growth, free-growing status, stocking standards, forest management plans, Coast–Interior Transition, British Columbia.

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