Quesnel TSA East

Documentation of
Vegetation Resources Inventory Statistical Analysis

Prepared for:
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EXECUTIVE SUMMARY

Mature green leading stands are a key component in the short and mid-term timber supply in the Quesnel TSA. Many of these stands are located in the eastern portion of the TSA. In order to assess the accuracy of the inventory in these stands for TSR5, 50 VRI Phase II samples were established among the 67 mapsheets in the eastern portion of the Quesnel TSA where mature green leading was the prevalent stand type. In particular, the Phase II sampling focused on vegetated treed (VT) stands that were at least 48 years old in 2009 and were leading in a species other than lodgepole pine (Pl).

The objective of this project was to complete a VRI statistical analysis of selected Phase I inventory attributes in the target population of interest to provide an assessment of the accuracy of the Phase I inventory. The analysis was based on current Ministry of Forests, Mines & Lands (MFLRNO) standards.

A total of 49 of the original 50 samples ultimately met the target population criteria. Post-stratification for the analysis was based on Phase I leading species and the resulting sample distribution was:

- Spruce leading (n=16)
- Balsam leading (n=9
- Fir leading (n=14)
- Other species (deciduous, etc.) leading (n=10)

The analysis focused on six inventory attributes: age, height, basal area/ha at 7.5cm+ dbh (BA), trees/ha at 7.5cm+ dbh (TPH), Lorey height, and volume/ha net dwb at 12.5cm+ dbh. The ratio of the weighted mean Phase II ground value to the weighted mean Phase I inventory value was computed for each attribute. A ratio greater than 1.0 suggests that, on average, the Phase I inventory is *under*estimating an attribute, based on the Phase II ground sample information. Similarly, a ratio less than 1.0 suggests that, on average, the Phase I inventory is *over*estimating the value of an attribute. The resulting VRI analysis ratios, and their associated sampling errors, are shown for each attribute, by stratum, in Table 1.

Table 1: Ratio of means comparisons (and sampling error % at a 95% confidence level) for six attributes, for the target population in the Quesnel TSA East, based on a VRISTART projection (using photo-estimated values of BA and TPH).

Leading species Stratum	n	VRISTART (photo-interpreted BA & TPH) Ratio of weighted means (with 95% sampling error shown as % of the ratio)					
		Age (years)	Height (m)	Basal area (m^2/ha at 7.5cm+ dbh)	Trees/ha (at 7.5cm+ dbh)	Lorey height (m)	Volume/ha (at 12.5cm+ dbh net dwb)
Spruce	16	0.861 (±8.8%)	0.949 (±9.7%)	0.805 (±23.6%)	1.203 (±33.8%)	0.860 (±14.8%)	0.828 (±31.8%)
Balsam	9	0.895 (±8.2%)	0.917 (±9.8%)	0.744 (±23.6%)	1.204 (±52.4%)	0.946 (±24.2%)	0.842 (±29.6%)
Fir	14	0.838 (±16.4%)	1.007 (±8.0%)	0.646 (±29.0%)	0.881 (±44.8%)	0.992 (±9.9%)	0.623 (±27.4%)
Other	10	0.906 (±20.2%)	1.073 (±6.9%)	0.822 (±25.8%)	0.724 (±35.7%)	1.105 (±10.2%)	1.008 (±32.7%)
Overall	49	0.870 (±7.2%)	0.989 (±4.4%)	0.741 (±13.1%)	0.995 (±21.1%)	0.969 (±7.0%)	0.780 (±15.8%)

Although photo-estimated values of basal area/ha and trees/ha were available on the Phase I inventory, there was concern about the accuracy of these attributes. Hence, the FIPSTART module of VDYP7 was also used to generate values for these attributes internally. A summary comparison of the FIPSTART (using internally generated BA and TPH) results are also shown below in Table 2.

Table 2: Ratio of means comparisons (and sampling error % at a 95% confidence level) for four attributes, for the target population in the Quesnel TSA East, based on a FIPSTART projection (VDYP7 internally generated values of BA and TPH).

Leading species Stratum	***n***	***FIPSTART (VDYP7-generated BA and TPH) Ratio of weighted means (with 95% sampling error shown as % of the ratio)***			
		Basal area (m^2/ha at 7.5cm+ dbh)	***Trees/ha (at 7.5cm+ dbh)***	***Lorey height (m)***	***Volume/ha (at 12.5cm+ dbh net dwb)***
Spruce	16	0.743 (±21.5%)	0.864 (±27.1%)	0.882 (±14.5%)	0.746 (±29.0%)
Balsam	9	0.846 (±16.0%)	1.014 (±37.1%)	0.968 (±22.9%)	0.966 (±27.8%)
Fir	14	0.728 (±21.1%)	0.779 (±31.0%)	1.004 (±8.9%)	0.706 (±19.5%)
Other	10	0.825 (±27.0%)	0.689 (±30.3%)	1.135 (±11.4%)	1.028 (±32.4%)
Overall	49	*0.773* (±11.2%)	*0.837* (±15.7%)	*0.989* (±6.8%)	*0.811* (±14.0%)

Overall, inventory volumes for the mature green in the eastern portion of the Quesnel TSA appear to be overestimated by about 25% on average, relative to the ground volume (ratio of ground to inventory volume was ~0.8). The volume overestimation appeared to be particularly severe in the Fir leading stratum however because of the small sample size and the relatively high sampling error in this stratum, results must be viewed with caution.

It appears that the largest bias among the inventory attributes is associated with basal area/ha. The sample suggests that using FIPSTART to generate values for BA and TPH rather than relying on the photo-interpreted estimates for these attributes slightly reduces the basal area bias, but this result varies by stratum. FIPSTART-generated BA appears to be closer, on average, to the ground BA in the Balsam and Fir leading strata. However, FIPSTART appears to do slightly poorer than photo-interpretation at estimating BA in the Spruce leading stratum. Once again, the stratum results must be interpreted with caution due to small sample sizes and high sampling error.

Since basal area is a major driver of volume estimation in the VDYP7 model, it was suspected that the observed volume overestimation in the mature green component of the eastern portion of the Quesnel TSA may be closely related to the overestimation of basal area. This was supported by results of an analysis of the relative contribution of error associated with volume estimation in the VDYP7 model and error associated with input attributes to the volume estimation process.

Based on issues encountered through the statistical analysis in this management unit, the following recommendations are made:

- Investigate the differences between the photo-interpreted and VDYP7-generated estimates of basal area and trees/ha in relation to the ground-based estimates to determine opportunities for improving the Phase I estimates for these attributes, either through changes in photo-estimation methodologies or FIPSTART design.

- Further develop definitions, terminology and graphical displays for the concept of model-related and attribute-related components of volume bias in the inventory.
- Develop a uniform extract from the LRDW for future VRI statistical analyses that provides a complete set of all attributes required for the analysis (including Lorey height, BA and TPH at 7.5cm+ dbh utilization) along with clear definitions (i.e. data dictionary).
- Utilize the Phase II sample data to test the inventory live/dead estimation methodology in management units where the methodology has been applied and Phase II data is available.
- This report is a technical document intended to provide complete details of the analysis. However, it is also recommended that a template for communicating these results in a uniform, succinct format suitable for wider distribution be developed.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the following Ministry of Forests, Lands and Natural Resource Operations staff for their guidance, assistance, advice and comments throughout this project: Graham Hawkins, Matt Makar, Sam Otukol and Will Smith.

Table of Contents

1. INTRODUCTION

1.1 Background

The Quesnel Timber Supply Area (TSA) has been significantly impacted by the Mountain Pine Beetle (MPB) infestation. In an effort to improve the way the Vegetation Resources Inventory (VRI) describes forests affected by MPB, a number of pilot programs have been implemented in the Quesnel TSA. One of these initiatives, completed in December 2009, was a new VRI Phase I inventory completed on 83 mapsheets that comprised the TSA.

Mature green leading stands are a key component in the short and mid-term timber supply in the TSA. Many of these stands are located in the eastern portion of the TSA. In order to assess the accuracy of the inventory in these stands for TSR5, 50 VRI Phase II samples were established among the 67 mapsheets in the eastern portion of the Quesnel TSA where mature green leading was the prevalent stand type. In particular, the Phase II sampling focused on vegetated treed (VT) stands that were at least 48 years old in 2009 and were leading in a species other than lodgepole pine (Pl). The pre-stratification for sample selection was based on age: young (48-120 years in 2009) and old (greater than 120 years in 2009).

Details of the sample planning for the Quesnel TSA East VRI Phase II can be found in the document *"Quesnel Timber Supply Area Vegetation Resources Inventory and Change Monitoring Inventory Ground Sampling: Sample Plan"* [1], which has been appended to this document for reference (see Appendix J).

1.2 Description of the Target Population Area

Table 1, excerpted from the sample plan document[2], indicates that the target population for the Quesnel TSA East VRI Phase II sampling represented approximately 35% of the total area in the TSA. The majority of the target population area was leading in spruce (about 33%), followed by stands leading in Douglas-fir (about 30%), balsam (at 15%) and aspen (at 14%).

Table 1: Quesnel TSA landbase indicating netdown for target population for VRI Phase II sampling.

Land Classification	*Area (ha)*	*% of TSA*
TSA (83 mapsheets)	***706,748***	***100.0***
TFLs (52 and 53)	78	0.0
Indian Reserves	2,727	0.4
Parks	2,112	3
Woodlots and Community Forests	44,607	6.3
Maps in West of TSA (16)	166,992	23.6
Area of Interest (67mapsheets)	***490,231***	***69.4***
Pl Leading	72,988	10.3
Stands < 48 years (in 2009)	149,270	21.1
Non Vegetated Treed	15,957	2.3
Target Population	***252,017***	***35.7***

[1] *"Quesnel Timber Supply Area Vegetation Resources Inventory and Change Monitoring Invneoty Ground Sampling: Sample Plan"*, Timberline Natural Resource Group Ltd., May 2010, 35pp.

[2] Ibid. 1

The location of the target population within the Quesnel TSA is illustrated in Figure 1 below[3].

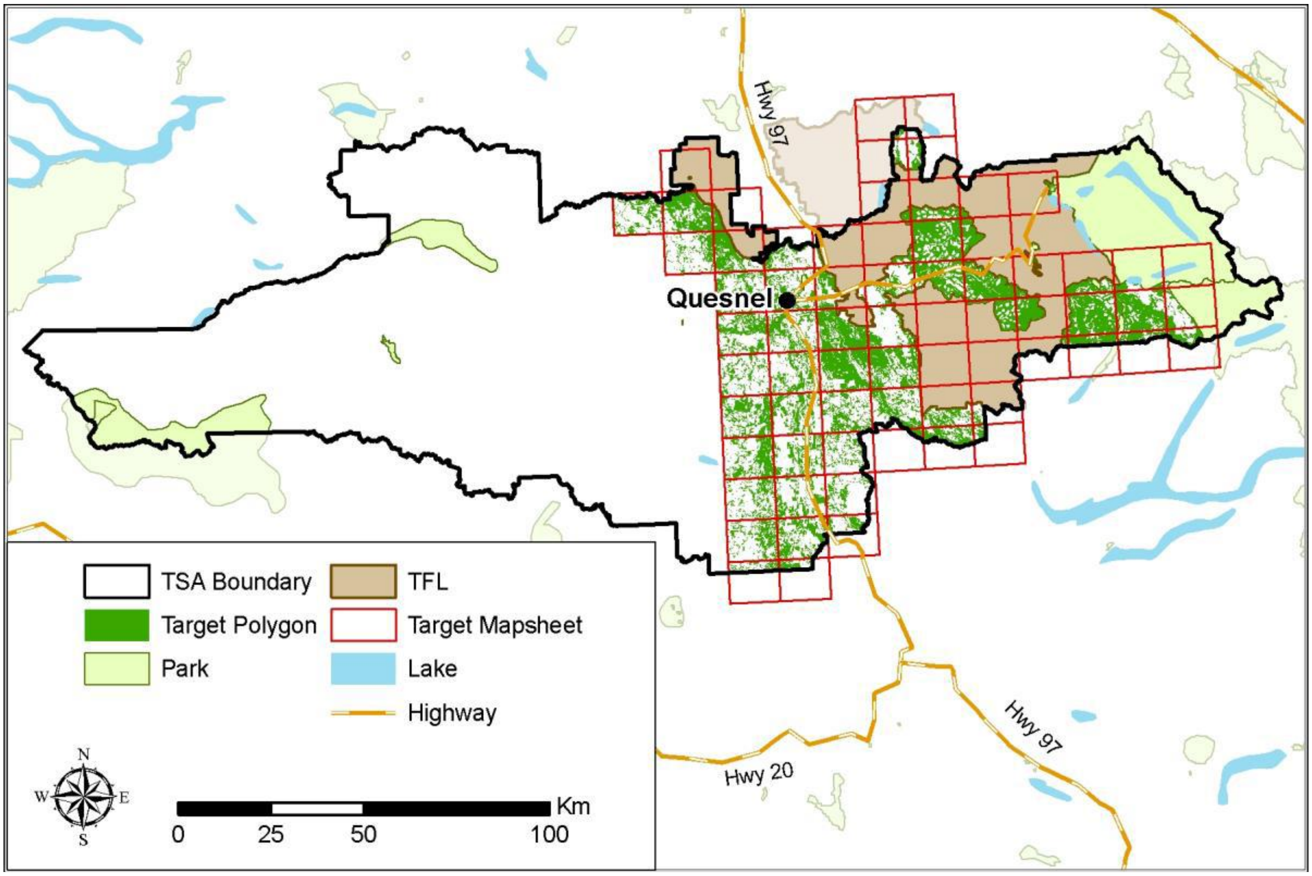

Figure 1: Map of the Quesnel TSA East Phase II target population.

1.3 Scope and Objectives

The objective of this project was to provide a VDYP7-based VRI statistical analysis for the Quesnel TSA East, based on current Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) standards. The analysis was to be based on the 50 Phase II samples established in the 2010 field season. Due to uncertainty regarding the accuracy of Phase I photo-estimation of basal area per hectare (BA) and trees per hectare (TPH) in this management unit the VRI statistical analysis was completed using the VRISTART module of VDYP7 and the original photo-estimated attributes as well as the using the FIPSTART module, in which VDYP7 generates estimates of BA and TPH internally.

In addition to the standard VRI statistical analysis, an examination of the bias associated with the inventory volume estimates was examined in more detail. Specifically, the relative contributions of the VDYP7 yield model itself and the inventory attributes used as input for the model were investigated.

Although dead volume was not recorded among the inventory attributes for this population of interest, estimates of dead volumes and BA based on the Phase II ground samples were provided as part of this analysis.

The Quesnel TSA East VRI statistical analysis was restricted to mature green, non-Pl leading, vegetated treed (VT) polygons greater than 47 years of age in 2009. Compiled Phase II data (including NVAF-adjusted volumes) and the Phase I data were provided by the MFLNRO. The development of statistical ratios of means

[3] Ibid. 1

and sampling errors were carried out in accordance with the recommended MFLNRO procedures as of September 2011. All attribute values were based on live trees only.

2. METHODS

2.1 Overview of VRI Statistical Analysis

The role of the VRI statistical analysis is to evaluate the accuracy of the Phase I photo-interpreted inventory data, using the Phase II ground sample data as the basis for the comparison.

The process involves first running the Phase I inventory data through the VDYP7 yield model to project the attributes to the same year as the ground sampling. The Phase I inventory data corresponding to the Phase II ground samples are identified and rigorous data checking and plots of the Phase II versus Phase I attribute values are carried out to screen for potential data errors and/or inappropriate matching of Phase I and II data. Analysis is usually done at the stratum level, where strata are typically defined by leading species[4]. After calculating and applying the appropriate sampling weights, mean values of the ground samples attributes and the corresponding Phase I inventory attributes are computed. Ratios of these two values (i.e. the mean Phase II ground sample value / the mean Phase I inventory value) are then calculated along with the corresponding sampling errors, by stratum.

These ratios of means, which are developed from the relationship between the Phase II ground sample values and the Phase I photo-interpreted inventory values for the set of polygons that comprised the VRI Phase II ground sample, form the basis of the inventory assessment. The sampling errors for these ratios can be used to interpret the risk and uncertainty associated with the sampling process.

There are six timber attributes that are considered in the current VRI ground sample data analysis:

- Age of the first species,
- Height of the first species,
- Basal area at 7.5cm+ dbh utilization (BA7.5),
- Trees per hectare at 7.5cm+ dbh utilization (TPH7.5),
- Lorey height[5] at 7.5cm+ dbh utilization (LH7.5), and
- Volume net top, stump (CU), decay, waste and breakage at 12.5cm+ dbh utilization.

2.2 Population for Analysis

The target population of interest for this analysis was the “mature green stratum” in the eastern portion of the Quesnel TSA (67 mapsheets), specifically, VT polygons greater than 47 years of age in 2009, where lodgepole pine was not the leading species. The total area of this population of interest was approximately 252,000 ha (see Table 1 in Section 1.2 for details).

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[4] The target population is usually pre-stratified prior to sample selection. Post-stratification may be required at the analysis stage particularly if significant bias trends are observed in the residuals plots of the data. However, post-stratification is generally restricted to subdivision of existing strata Analysis stratification that differs greatly from the original sample selection stratification is usually very inefficient and is not recommended. However, analysis sub-stratification within the original sample selection strata may be used to distinguish important trends if a sufficient number of samples are available. The need for sub-stratification can often be deduced from the plots of residual values.

[5] Lorey height is mean height, weighted by tree basal area. This height measure is generally more stable than unweighted mean height and is an important input attribute in the VDYP7 yield prediction model.

2.3 Phase II Sample Selection Pre-Stratification and Weights

For the sample selection, pre-stratification was carried out based on age groupings: young (48 – 120 years in 2009) and old (greater than 120 years in 2009). Further sub-stratification, by leading species group, was also applied in the sample selection to ensure adequate representation of the samples across the target population.

Sampling weights were determined from area information presented in the *"Quesnel TSA VRI and CMI Sample Plan"*[6]. The weights, as calculated in Table 2 below, were applied in the analysis. Note that only 49 of the original 50 samples were used in the analysis (see Section 2.4.3 for details). As a result, the weight for samples in "Old FD" were adjusted to account for the loss of one sample in this sub-stratum.

Table 2: Sample weights for the Quesnel TSA East Audit Analysis.

Stratum	*Sub-stratum*	*Area (ha)*	*n*	*Weight (number of hectares represented by each sample) = A/n*
Young (48-120 yrs)	S & BL	27,677	5	5535
	FD	38,404	7	5486
	Other	42,773	8	5347
Old (120 yrs+)	S & BL	95,249	20	4762
	FD	36,335	7	5191
	Other	11,579	2	5790
total		252,017	49	

Although the initial sample selection stratification was age-based, in discussions with MFLNRO staff[7] it was decided that analysis stratification based on Phase I leading species (i.e. spruce, balsam, fir and other) would provide a more meaningful assessment of the Phase I inventory accuracy. As a result, individual samples within an analysis stratum may have sampling weights that differ from other samples in the same stratum. However, the difference among the weights is relatively small hence there is minimal risk of one sample within an analysis stratum having undue influence as a result of disparate sampling weights.

The distribution of the samples among the analysis strata is provided in Table 3.

Table 3: Distribution of Phase II samples by analysis stratum.

Inventory leading species stratum	*n*
Spruce	16
Balsam	9
Fir	14
Other	10
All	*49*

[6] *"Quesnel Timber Supply Area Vegetation Resources Inventory & Change Monitoring Inventory Ground Sampling: Sample Plan"*, Timberline Natural Resource Group Ltd., May 2010, 35pp.

[7] September 6, 2011 conference call.

2.4 Data Sources

2.4.1 Phase I photo-interpreted inventory data

Inventory data from the LRDW, projected to 2010, was provided by the Ministry. Since ground sampling was also completed in 2010, values on this file for age, height and volume were used directly in the analysis. However, values for BA, TPH and LH were not available at the 7.5cm+ dbh utilization as required for the audit analysis hence VDYP7 Console was used (in conjunction with input values and reference year) to obtained projected values for these attributes at the required utilization.

The inventory for this management unit is relatively new; reference dates for the samples were all between 2005 and 2007. No estimates of dead pine were available on the inventory files (see Section 3.4), presumably because the dead pine % in the target population did not meet the minimum criterion required to invoke the live/dead estimation methodology for the inventory volume.

The main analysis for the Quesnel TSA East was completed using the photo-interpreted basal area and trees/ha as provided on the inventory file. Since all sample polygons recorded a V-type inventory standard, the inventory data would have been projected using the VRISTART mode of VDYP7. The results for this portion of the analysis are provided in Section 3.1.

The scope of the analysis also included running the VDYP7 projection of the inventory data as an F-type inventory standard. That is, basal area and trees/ha were generated in the FIPSTART module of VDYP7 rather than using the photo-interpreted values for these attributes. The results for this portion of the analysis are presented in Section 3.2.

The Phase I inventory attributes used in the analysis (with both the photo-interpreted and FIPSTART-generated basal area and trees/ha values) are shown in Appendix A.

2.4.2 Phase II ground sample data

The sample plan document indicates that 50 samples were selected for establishment in the eastern portion of the Quesnel TSA. The Phase II data was compiled by MFLNRO and included application of the most up-to-date regional NVAF values. This file was provided by Will Smith (MFLNRO) on August 3, 2011.

The compiled data was provided under project number 0261. Note that sample #41 was inadvertently selected based on its rank 2 characteristics (rather than rank 1). Since the rank 1 stand did not meet the population of interest criteria (i.e. it was a 35 year old, Pl leading stand), this sample was excluded from the analysis, leaving a total of 49 samples.

The Phase II compiled ground sample attributes used in the analysis are provided in Appendix B.

2.4.3 Data issues related to the statistical adjustment

As detailed in Section 2.4.2, sample #41 was excluded from the analysis since it did not meet the population of interest criteria.

Scatterplots comparing the Phase I and Phase II attributes were examined for outliers. Large differences between the ground sample and photo-based estimates of BA (and corresponding volume) were noted for a number of samples[8]. Details are provided in Appendix C. Although no changes were made to the data used in the analysis, it was decided to examine the impact of using FIPSTART-generated values for BA and TPH as a means to improve the photo-estimated values for these attributes. Results are presented in Section 3.2.

[8] A description of this issue was forwarded to the Ministry on September 12, 2011 for further investigation (Quesnel TSA East Audit Analysis – BA outliers.doc).

As per discussions at a Sept 6, 2011 meeting with MFLNRO staff, analysis stratification was based on Phase I leading species: Spruce, Balsam, Fir and Other.

2.4.4 Height and Age data matching

The data matching used to determine the appropriate Phase I and II heights and ages upon which to base the comparison ratios followed the same basic approach outlined in the MFLRNO procedures and standards document.

For each VRI sample polygon, the Phase II ground sample data was matched with the corresponding Phase I inventory data for the same polygon. The ground heights and ages used in the analysis were based on the average values for the T, L, S, X & O trees[9] for the ground leading species (by basal area at 4cm + dbh utilization) on the ground. The objective in the matching process was to choose an inventory height and age (i.e. for either the leading or second species) so that the ground and inventory species "matched".

If a leading species match could not be made at the sp0[10] level, conifer-to-conifer (or deciduous-to-deciduous) matches were allowed. However, conifer-deciduous matches were not considered acceptable. Appendix D provides the details for the height and age data matching. Appendix E provides a comparison between the Phase I inventory leading species and the Phase II ground sample leading species.

Of the 49 samples used in the analysis, 30 (or 61%) indicated a match between the inventory leading species and the ground leading species at 4cm+ dbh utilization. A further 14 samples (29%) were matched based on the inventory second leading species. Four (4) samples were matched on a conifer-to-conifer or deciduous-to-deciduous basis. Only one sample could not be matched and was therefore excluded from the development of the age and height comparison ratios[11]. However, all samples were used in the development of basal area, trees/ha, Lorey height and volume ratios.

3. RESULTS AND DISCUSSION

3.1 VRI statistical analysis (VRISTART projection)

As a way to compare the Phase I inventory values with the Phase II ground sample values, ratios of the weighted mean Phase II ground sample attribute over the corresponding weighted mean Phase I inventory attribute were computed. The ratios of means were calculated for each of the six key attributes identified in Section 2.1, for each stratum as well as over all samples. The analysis stratification was based on Phase I inventory leading species. The resulting weighted means are shown in Table 4. The ratios of means, and the sampling error associated with each of these statistics, are provided in Table 5. Note that the analysis in this section is based on photo-interpreted basal area and trees/ha values and a VDYP7 VRISTART projection.

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[9] T or "top height" tree is the largest DBH in 0.01 ha plot, regardless of species; L or "leading species" tree is the largest DBH in 0.01 ha plot, of leading species; S or "second species" is the largest DBH in 0.01 ha plot, of second species. T and S trees are selected and measured at the IPC only whereas L trees are selected at the IPC and all auxiliary plots. If a suitable (age or height) leading species sample tree is not found in any given plot in a cluster, a "replacement" tree will be selected. An "O" tree is the closest suitable (for height and age) tree of the leading species to the 5.64m radius plot center. An "X" tree is the closest suitable tree of the leading species outside of the 5.64m radius plot but within a maximum 25m radius of plot centre. For further details, refer to the MFLNRO document "VRI Ground Sampling Procedures Version 4.8, May 2008, Amendment # 1: Modifications to the Leading Species Site Tree Selection Procedures", April, 2009.

[10] sp0 refers to the 16 major species codes and is roughly equivalent to the genus level.

[11] Sample #43.

Table 4: Sample-estimated weighted means for the Phase I inventory and Phase II ground sample for six key inventory attributes, for the target population in the Quesnel TSA East, based on a ***VRISTART*** projection.

Attribute	***Weighted Means, by leading species stratum***				
	Spruce	Balsam	Fir	Other	***All strata***
Age (years)					
n	16	9	13	10	48
Phase II Ground	131	150	100	94	117
Phase I Inventory	152	168	119	104	135
Height (m)					
n	16	9	13	10	48
Phase II Ground	24.8	20.3	27.9	27.7	25.5
Phase I Inventory	26.1	22.1	27.7	25.8	25.8
Basal area (m2/ha) at 7.5cm+ dbh					
n	16	9	14	10	49
Phase II Ground	24.1	28.9	26.4	24.8	25.8
Phase I Inventory[12]	29.9	38.8	40.8	30.2	34.8
Trees/ha at 7.5cm+ dbh					
n	16	9	14	10	49
Phase II Ground	591	959	567	486	625
Phase I Inventory[13]	491	796	643	671	628
Lorey height (m)					
n	16	9	14	10	49
Phase II Ground	20.1	17.3	24.4	26.0	22.2
Phase I Inventory	23.3	18.3	24.6	23.5	22.9
Volume/ha (m3/ha) at 12.5cm+ dbh net dwb					
n	16	9	14	10	49
Phase II Ground	181	186	200	187	189
Phase I Inventory	218	221	321	186	242

The relationship between the Phase II ground and the Phase I inventory attributes corresponding to each ratio were examined in scatterplots (Appendix F). The ratios of means were also evaluated for potential bias by plotting the "residual" values[14] as a function of the ratio-adjusted (or "estimated") value for each attribute. In addition, the residuals were plotted as a function of unadjusted inventory age as a check for any age-related trends in the ratios. These graphs are also included in Appendix F.

Careful examination of the scatterplots in Appendix F did not suggest any significant bias patterns associated with the ratios of means. However, many of the graphs illustrated a weak relationship between the ground and the inventory attribute values and a high level of variability.

[12] Based on the photo-estimated values projected using the VRISTART module in VDYP7.

[13] Ibid.

[14] A "residual" is computed as *actual minus estimate*. In this case, the actual is the Phase II sample value and the estimate is the ratio-adjusted Phase I value (i.e. Phase I value multiplied by the ratio of means value).

Table 5: Ratio of means comparisons (and sampling error % at a 95% confidence level) for six attributes, for the target population in the Quesnel TSA East, based on a ***VRISTART*** projection.

Leading species Stratum	*n*	*Ratio of weighted means (with 95% sampling error shown as % of the ratio)*					
		Age (years)	*Height (m)*	*Basal area[15] (m^2/ha at 7.5cm+ dbh)*	*Trees/ha[16] (at 7.5cm+ dbh)*	*Lorey height (m)*	*Volume/ha (m^3/ha at 12.5cm+ dbh net dwb)*
Spruce	16	0.861 (±8.8%)	0.949 (±9.7%)	0.805 (±23.6%)	1.203 (±33.8%)	0.860 (±14.8%)	0.828 (±31.8%)
Balsam	9	0.895 (±8.2%)	0.917 (±9.8%)	0.744 (±23.6%)	1.204 (±52.4%)	0.946 (±24.2%)	0.842 (±29.6%)
Fir	14[17]	0.838 (±16.4%)	1.007 (±8.0%)	0.646 (±29.0%)	0.881 (±44.8%)	0.992 (±9.9%)	0.623 (±27.4%)
Other	10	0.906 (±20.2%)	1.073 (±6.9%)	0.822 (±25.8%)	0.724 (±35.7%)	1.105 (±10.2%)	1.008 (±32.7%)
Overall	*49*	*0.870 (±7.2%)*	*0.989 (±4.4%)*	*0.741 (±13.1%)*	*0.995 (±21.1%)*	*0.969 (±7.0%)*	*0.780 (±15.8%)*

The ratios of means in Table 5 can be used to assess the accuracy of selected attributes within the Phase I inventory. Since the ratios are computed as the Phase II value over the Phase I value, *a ratio of means greater than 1 suggests that the Phase I attribute is underestimated*. Similarly, *a ratio of means value less than 1 indicates that the Phase I is overestimating* the attribute value.

The sample suggests that, on average, age is overestimated among all strata in the mature green target population in the Quesnel TSA East, with an average overestimation of about 15% relative to the average ground age[18] (ratio of means = 0.87). Trends in height estimation bias among the strata are less clear, with very little bias in this attribute overall. Overall bias for the trees/ha and Lorey height attributes were also relatively minor, although there was considerable variability in the results among strata, particularly for trees/ha.

On average, the sample suggests that the Phase I basal area is overestimated by roughly 35% on average, relative to the ground basal area[19] (ratio of means = 0.74). Basal area overestimation in the inventory is a trend that is apparent in all strata that were sampled. The largest overestimation was observed in the Fir leading stratum, where the average inventory basal area was overestimated by over 50% relative to the ground sample average basal area. However, the small sample size and relatively large sampling error suggest caution in interpreting stratum results.

The assessment for volume estimation is discussed separately in the next section.

[15] In Tables 4 and 5, the analysis was based on photo-estimated values of the basal area and trees/ha attributes projected using the VRISTART routine within VDYP7.

[16] Ibid

[17] In this stratum, age and height means and ratios are based on 13 samples (see section 2.4.4).

[18] Computed as: ((Ground vol –Inventory vol)/Ground vol) X 100%= (1- (Inventory vol/Ground vol))X100%

[19] Ibid

3.1.1 Assessment of Phase I inventory volume accuracy (VRISTART projection)

Since volume estimation and yield projection are important components of the VRI inventory and play a key role in timber supply analyses, the information in Tables 4 and 5 have been restated in Table 6 to focus the discussion on volume. Timber supply analyses are typically done on a net decay, waste and breakage volume basis. Hence, the volume/ha accuracy assessment and its associated sampling error is computed on this basis. As was the case for the other attribute comparisons (Section 3.1), the ratios of means for volume were computed as ratios of the weighted mean Phase II (ground sample) volume to the weighted mean Phase I (VDYP7) volume. Hence a ratio greater than 1 indicates that the Phase I inventory is underestimating volume and a ratio less than 1 indicates that the Phase I inventory is overestimating volume. The results, by stratum, are shown in Table 6.

The Phase II ground sample suggests that, on average, the Phase I inventory volumes for the mature green target population in the eastern portion of the Quesnel TSA are consistently overestimated across all strata with the exception of the Other leading species (i.e. non-spruce, non-balsam, non-fir) stratum. For this stratum, the volume estimation bias was minimal, although the sampling error was relatively high.

For both the Spruce and the Balsam leading strata, the estimated volume ratio of means was about 0.83 suggesting that the inventory was overestimating volume by about 20% relative to the average Phase II ground volume[20]. The magnitude of the volume overestimation suggested by the sample in the Fir leading stratum was even greater. For samples in the Fir leading stratum, it was estimated that inventory volumes were overestimated by about 60% on average, relative to the Phase II ground sample volumes. Note that the sampling errors in these strata were high (between ±27.4% and ±31.8%) hence these strata results must be interpreted with caution.

Table 6: Assessment of Phase I inventory volume accuracy (assuming "F"-type inventory), based on the Phase II ground sample, for the target population in the Quesnel TSA East, based on a ***VRISTART*** projection.

Assessment of Phase I inventory volume (m³/ha) estimates @12.5cm+ dbh utilization net DWB					
Leading species stratum	***n***	***Weighted Mean Phase II vol/ha***	***Weighted Mean Phase inventory vol/ha***	***Estimated ratio of means volume comparison***	***Sampling error % for volume ratio (at 95% confidence level)***
Spruce	16	181	218	0.828	±31.8%
Balsam	9	186	221	0.842	±29.6%
Fir	14	200	321	0.623	±27.4%
Other	10	187	186	1.008	±32.7%
Overall	*49*	*189*	*242*	*0.780*	*±15.8%*

3.1.2 Sampling error (VRISTART projection)

The sampling error estimates in Tables 5 and 6 were computed using the MFLNRO's Excel-based macro tool[21]. These values can provide an indication of the reliability of the sample-based estimated ratios of means.

Although no sampling error targets were explicitly stated in the ground sample plan, the overall 15.8% sampling error achieved with the 49 samples established in this project would allow reasonable confidence in the overall ratio of means. However, there is considerably less certainty regarding results on a stratum basis.

[20] Computed as: ((Ground vol –Inventory vol)/Ground vol) X 100%= (1- (Inventory vol/Ground vol))X100%

[21] "VRI Analysis Workbook 2010-10-29_Test_mod.xlsm" provided by Sam Otukol, MFLRNO.

3.2 Analysis of Inventory BA, TPH, LH and Volume Based on FIPSTART

As a result of concerns regarding the accuracy of photo-estimated BA and TPH in this management unit, the audit analysis of BA, TPH, LH and volume was also completed using the FIPSTART module of VDYP7 to generate BA and TPH values. Since the projected values of age and height in VRISTART and FIPSTART are the same, these attributes were not included in the FIPSTART results shown in Tables 7-10 that follow.

Graphs showing the relationship between the Phase II ground and the FIPSTART-generated Phase I attributes are provided in Appendix G. Appendix H shows a comparison of the VRISTART and FIPSTART Phase I estimates of BA relative to the Phase II ground values. Although FIPSTART values for basal area/ha appear to be closer to ground values in the Balsam and Fir leading strata, trends in the Spruce and Other strata are less clear[22].

Overall, the sample results suggested that the FIPSTART-generated values of BA, Lorey height and volume showed slightly less bias than the VRISTART photo-estimated values, when compared with the Phase II ground sample values. However the sample did not indicate any overall improvement in TPH bias for FIPSTART compared to VRISTART.

Table 7: Audit results for basal area/ha at 7.5cm+ dbh utilization, for the target population in the Quesnel TSA East, based on FIPSTART**.** The 95% confidence intervals are shown in brackets below the ratios.

Leading species stratum	***Basal area/ha (m^2/ha) at 7.5cm+ dbh***				
	n	*Wtd Mean Phase II (ground)*	*Wtd Mean FIPSTART Phase I (inventory)*	*FIPSTART Ratio of means*	*VRISTART Ratio of means (for comparison)*
Spruce	16	24.1	32.4	0.743 (±21.5%)	0.805 (±23.6%)
Balsam	9	28.9	34.1	0.846 (±16.0%)	0.744 (±23.6%)
Fir	14	26.4	36.2	0.728 (±21.1%)	0.646 (±29.0%)
Other	10	24.8	30.1	0.825 (±27.0%)	0.822 (±25.8%)
Overall	*49*	*25.8*	*33.3*	*0.773* (±11.2%)	0.741 (±13.1%)

[22] It was also hypothesized that over time, VDYP7 projected values of BA and TPH in VRISTART might converge with FIPSTART values. However, since the Phase I in this management unit is relatively recent and the projection period is short (3 to 5 years), there was insufficient evidence to support this.

Table 8: Audit results for trees/ha at 7.5cm+ dbh utilization, for the target population in the Quesnel TSA East, based on FIPSTART**.** The 95% confidence intervals are shown in brackets below the ratio of means.

Leading species stratum	*Trees/ha at 7.5cm+ dbh*				
	n	*Wtd Mean Phase II (ground)*	*Wtd Mean FIPSTART Phase I (inventory)*	*FIPSTART Ratio of means*	*VRISTART Ratio of means (for comparison)*
Spruce	16	591	684	0.864 (±27.1%)	1.203 (±33.8%)
Balsam	9	959	945	1.014 (±37.1%)	1.204 (±52.4%)
Fir	14	567	728	0.779 (±31.0%)	0.881 (±44.8%)
Other	10	486	704	0.689 (±30.3%)	0.724 (±35.7%)
Overall	*49*	*625*	*747*	*0.837* (±15.7%)	0.995 (±21.1%)

Table 9: Audit results for Lorey height at 7.5cm+ dbh utilization, for the target population in the Quesnel TSA East, based on FIPSTART**.** The 95% confidence intervals are shown in brackets below the ratio of means.

Leading species stratum	*Lorey height (m) at 7.5cm+ dbh*				
	n	*Wtd Mean Phase II (ground)*	*Wtd Mean FIPSTART Phase I (inventory)*	*FIPSTART Ratio of means*	*VRISTART Ratio of means (for comparison)*
Spruce	16	20.1	22.8	0.882 (±14.5%)	0.860 (±14.8%)
Balsam	9	17.3	17.9	0.968 (±22.9%)	0.946 (±24.2%)
Fir	14	24.4	24.3	1.004 (±8.9%)	0.992 (±9.9%)
Other	10	26.0	22.9	1.135 (±11.4%)	1.105 (±10.2%)
Overall	*49*	*22.2*	*22.4*	*0.989* (±6.8%)	0.969 (±7.0%)

Table 10: Audit results for volume/ha at 12.5cm+ dbh utilization net dwb, for the target population in the Quesnel TSA East, based on FIPSTART**.** The 95% confidence intervals are shown in brackets below the ratio of means.

Leading species stratum	*Volume at 12.5cm+ dbh net dwb*				
	n	*Wtd Mean Phase II (ground)*	*Wtd Mean FIPSTART Phase I (inventory)*	*FIPSTART Ratio of means*	*VRISTART Ratio of means (for comparison)*
Spruce	16	181	242	0.746 (±29.0%)	0.828 (±31.8%)
Balsam	9	186	193	0.966 (±27.8%)	0.842 (±29.6%)
Fir	14	200	283	0.706 (±19.5%)	0.623 (±27.4%)
Other	10	187	182	1.028 (±32.4%)	1.008 (±32.7%)
Overall	*49*	*189*	*233*	*0.811* (±14.0%)	0.780 (±15.8%)

3.3 Model-Related and Attribute-Related Components of Volume Bias

The volume ratios of means, comparing the mean Phase I inventory volume with the mean Phase II ground sample volume, provide an estimate of the total bias in volume estimation for the mature green target population in the eastern portion of the Quesnel TSA. The results in Table 10 suggest that the Phase I inventory overestimates volume by roughly 25% relative to the Phase II ground volume (based on a ratio of ground to inventory volume of about 0.8).

In the VRI inventory, estimates of volume for a polygon are generated by the VDYP7 yield model, based on a set of input attributes that are typically photo-estimated. As such, this creates two main sources or two potential underlying causes for the volume bias that we observe when we compare the Phase I inventory volume with the Phase II ground volume. These two underlying causes, which each contribute independently and in an additive fashion to the total volume bias, are:

1. Attribute-related volume bias: bias associated with providing the yield model with incorrect input attributes i.e. biased photo-estimates of inventory attributes for a polygon (e.g. species composition, height, age, basal area, trees/ha).
2. Model-related volume bias: bias associated with poor prediction by the VDYP7 yield model (independent of the input attributes i.e. assuming a correct set of input attributes).

Understanding the cause or source of the volume bias in a management unit may help to focus future efforts for improving volume estimation in the inventory.

Estimates of the relative contribution of each of these bias components to the total inventory volume bias can be obtained by creating a new volume estimate using the polygon attributes from the ground sample (to remove the bias associated with the photo-estimation of these attributes) as inputs to the VDYP7 yield model.

In this manner, the model-related volume bias can be approximated by computing the difference between the ground sample volume and the VDYP7 volume using the ground attributes as input[23]. Attribute-related volume bias can be approximated by computing the difference between the VDYP7 inventory volume (using the photo-estimated attributes as input) and the VDYP7 volume using the ground attributes as input[24]. In each case, either the “model” or the “attributes” are held constant to isolate their respective effects on volume estimation.

The results of the analysis of model-related and attribute-related volume bias in the mature green target population in the eastern portion of the Quesnel TSA are shown in Table 11. Note that this analysis was carried out for volume at a 7.5cm+ dbh net dwb utilization[25]. Volume comparisons elsewhere in this report are based on a 12.5cm+ dbh utilization.

[23] To estimate model bias, the bias associated with the inputs to VDYP7 is removed by using the ground attributes, which are assumed to be “correct”. Since the ground attributes are used as inputs for both volume computations (i.e. VDYP7 and the compiler), any resulting volume differences are then attributed to the “model”. That is, the ground sample compiler (which is assumed to be accurate) is compared as directly as possible to the VDYP7 yield prediction model.

[24] To estimate the attribute-related bias component of the total volume bias, the same “model” is used (i.e. VDYP7 in both cases) but volumes using the ground attributes (which are assumed to be accurate) as inputs to VDYP7 are compared to volumes using the photo-estimated attributes as inputs to VDYP7.

[25] Since the VDYP7 model is calibrated at the 7.5cm+ dbh volume utilization, it was thought that this basis would provide a more accurate picture of the model bias component.

Table 11: Weighted mean volumes at 7.5cm+ dbh net dwb, by stratum.

Stratum	*n*	*Weighted Mean Volume/ha net dwb at 7.5cm+ dbh*					
		Phase II Ground **A**	*VDYP7 Phase I Inventory (photo attributes)* **B**	*VDYP7 volume with ground attributes as input* **C**	*Model-related volume bias* **A-C**	*Attribute-related volume bias* **C-B**	*Total volume bias* **A-B**
Spruce	16	182	218	164	18	-54	-36
Balsam	9	191	222	147	44	-75	-31
Fir	14	203	321	202	1	-119	-118
Other	10	192	187	173	19	-14	5
Overall	***49***	***192***	***242***	***174***	***18***	***-68***	***-50***

The difference between the ground volume and inventory volume (Table 11 column A – column B), referred to as the total volume bias, was -50 m3/ha, indicating that, on average, the inventory is overestimating the volume by about 50 m3/ha or about 26% relative to the ground volume. The model-related volume bias (column A – column C) was +18 m3/ha, indicating that the VDYP7 model (assuming correct input attributes) actually underestimates volume by about 9%. The attribute-related component of the volume bias (column C – column B), on the other hand, was -68 m3/ha, indicating that the photo-estimated input attributes account for a volume overestimation bias of nearly 40%.

It is important to note that for the target population in the Quesnel TSA East, the model-related bias, which underestimates volume in this case, mitigates a portion of the attribute-related bias, which overestimates volume. However, the net effect of the combination of model and attribute-related volume bias, here referred to as total volume bias, is still a significant volume overestimation in this management unit. The relationship between model and attribute bias is shown pictorially in Figure 2.

In other areas of the province, it is possible that both the model and attribute-related volume biases may contribute to the total volume bias in the same direction (i.e. both may work to overestimate volume or both may work to underestimate volume). Yet in other areas, the input attributes may work to underestimate volume at the same time that the VDYP7 model itself (given correct inputs) would overestimate volume. Hence, the direction or sign of the bias components are important to note in this type of analysis.

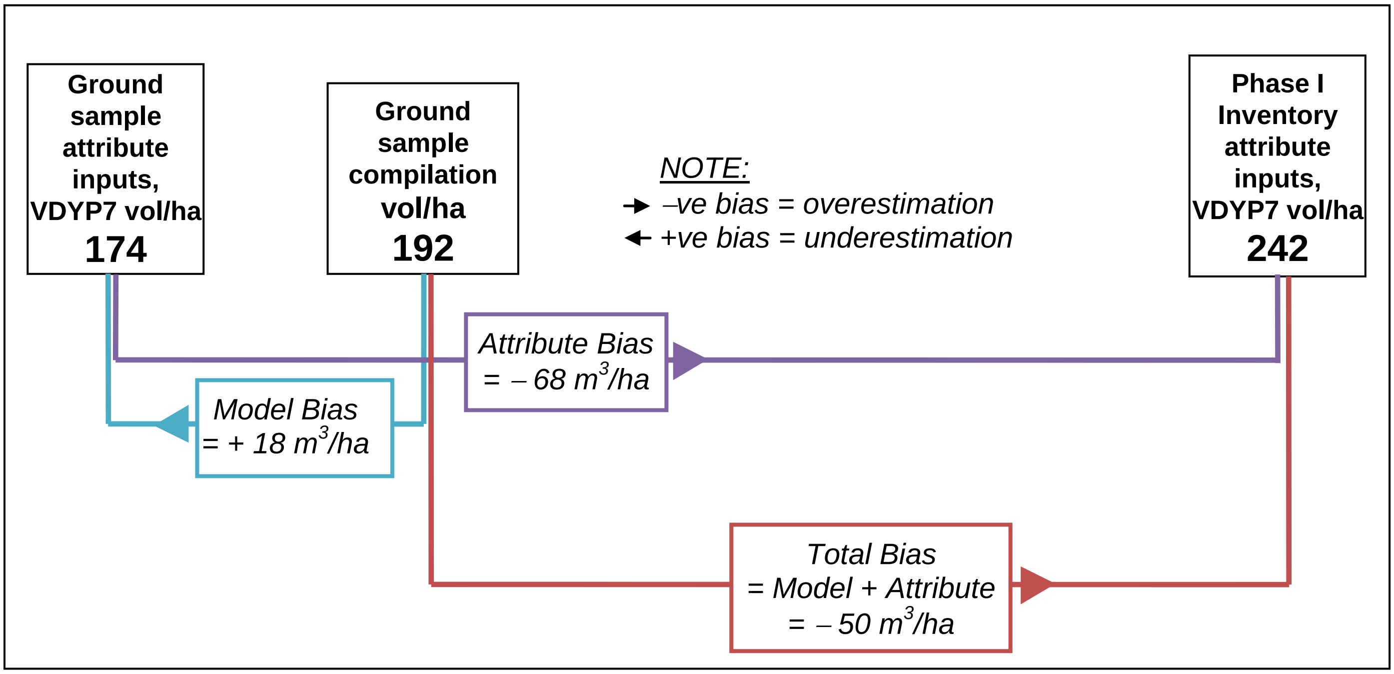

Figure 2: Relationship between the model and attribute-associated components of total volume bias for the target population in the eastern portion of the Quesnel TSA.

Graphs representing the total volume bias, as well as the model and attribute-related volume bias, by stratum, are provided in Appendix I. Table 12 shows the ratios of means corresponding with the total volume bias, and the model and attribute-related volume biases as well as their associated sampling errors.

On a stratum basis, the greatest total volume bias was seen in the Fir leading stratum, where the sample suggested that volumes were overestimated by about 58% relative to the ground volumes[26] (ratio of means = 0.63). Within this stratum, virtually all of the observed volume bias was related to attribute estimation; the VDYP7 yield model itself showed very little bias in this stratum.

The sample indicated that the VDYP7 yield model underestimated volume among all strata, but this volume underestimation was usually 10% or less. The notable exception was the Balsam leading stratum, where the sample suggested that the VDYP7 model significantly underestimated volume. However, in this stratum the volume *under*estimation bias associated with the VDYP7 model was mitigated by a volume *over*estimation bias associated with the photo-interpreted inventory attributes. The net effect or the total volume bias for the Balsam stratum, as estimated by the sample, indicated that the inventory overestimated volume.

The correlation between the ground volume and the “ground attribute volume” (i.e. VDYP7 volume using the ground attributes as inputs) was generally quite high and the variability in the ratio of means was low, with stratum sampling errors for model-related bias typically 10% or less. However the attribute-related bias relationships were considerably more variable. This is clearly illustrated among the graphs in Appendix I.

[26] Computed as: ((Ground vol –Inventory vol)/Ground vol)X100% = (1- (Inventory vol/Ground vol))X100%

Table 12: Ratios of mean volumes (7.5cm+ dbh net dwb) representing total, model and attribute bias, with associated sampling error % at a 95% confidence level.

Stratum	*n*	*Ratio of Weighted Mean Volume/ha net dwb at 7.5cm+ dbh*		
		***Total Bias**: Ground/Inventory (col A/B)*	***Model Bias**: Ground/ VDYP7(ground attributes) (col A/C)*	***Attribute Bias**: VDYP7 (ground attributes) / Inventory (col C/B)*
Spruce	16	0.834 (±31.5%)	1.110 (±5.2%)	0.752 (±30.3%)
Balsam	9	0.864 (±28.8%)	1.300 (±10.4%)	0.665 (±30.1%)
Fir	14	0.631 (±27.8%)	1.003 (±9.7%)	0.629 (±31.5%)
Other	10	1.026 (±31.7%)	1.105 (±7.4%)	0.929 (±30.4%)
Overall	***49***	***0.791 (±15.6%)***	***1.100 (±4.0%)***	***0.720 (±14.9%)***

Basal area/ha is known to be an important driver of volume in the VDYP7 model. The magnitude of the contribution of basal area estimation to the attribute-related bias component of total volume bias was examined in two ways, from two slightly different perspectives. The overall results are provided in Table 13.

First, the VDYP7 volumes were computed using, as inputs, all ground attributes with the exception of photo-estimated basal area (see column D in Table 13). From this perspective, it appears that about 82% of the overall attribute bias was generated by incorrect photo-estimated basal area i.e. 56 m^3/ha (col. D-C) out of the 68 m^3/ha (col. B-C) attribute bias[27]. Secondly, VDYP7 volumes were computed using all photo-estimated attributes with the exception of ground-based basal area (see column E in Table 13). From this alternate perspective, it appears that almost 90% of the attribute bias can be corrected by substituting the correct ground basal area alone (i.e. 61 m^3/ha out of the 68 m^3/ha attribute bias). It is hypothesized that the slight differences in the results from these two perspectives is due to the internal relationships in VDYP7 between basal area and other attributes. Nonetheless, these tests clearly indicate the dominant contribution of basal area estimation bias to the attribute bias component of the observed overall volume estimation bias. The remainder of the attribute bias, as it affects volume estimation, can be attributed to differences in species composition, age, height, trees/ha, crown closure, etc.[28].

Table 13: Influence of basal area on attribute-related volume bias.

Stratum	*n*	*Weighted Mean Volume/ha net dwb at 7.5cm+ dbh*			
		Phase I VDYP7 Inventory (photo attributes) ***B***	*VDYP7 with ground attributes* ***C***	*VDYP7 with ground attributes **except photo BA*** ***D***	*VDYP7 with photo attributes **except ground BA*** ***E***
Spruce	16	218	164	198	176
Balsam	9	222	147	199	165
Fir	14	321	202	304	214
Other	10	187	173	201	156
Overall	***49***	***242***	***174***	***230***	***181***

[27] Attribute-related volume bias = 68 m3/ha = column B – column C.

[28] Also non-vegetated features such as rock% and vegetated features such as shrub/herb/bryoid %.

3.4 Analysis of Dead Pine

With the prevalence of the Mountain Pine Beetle (MPB), the MFLNRO has developed a methodology to estimate and reflect the dead volume proportion in a stand as an inventory attribute. Under this methodology, dead volume estimates are produced so long as a minimum 30% dead pine threshold criterion is met.

The Phase I inventory for the eastern portion of the Quesnel TSA is relatively recent, with most reference years for the samples in this analysis falling between 2005 and 2007. In combination with the fact that mature green, non-pine leading polygons were targeted for sampling, this resulted in a low pine component among the samples. Consequently, the inventory did not meet the threshold of a minimum of 30% dead pine, and the Ministry's live/dead estimation methodology was not applied to this area. As a result, there were no Phase I estimates of dead pine volume available for the samples and a comparison with the Phase II dead pine volumes could not be completed.

However, the Phase II data was examined to provide estimates of the actual dead pine volume and basal area in this management unit. The results are summarized in Tables 14 and 15 respectively.

The Phase II ground sample estimates of dead volume from the compilation suggested that, on average, less than 30% of the volume was dead pine. The Phase I inventory for this project does not show dead pine volume, presumably because the area did not meet the minimum 30% dead pine required to invoke the dead pine estimation methodology in the inventory. Hence the Phase II results confirm that there was indeed less than 30% dead pine in this target population.

Table 14: Summary of dead PL volume in the Phase II ground samples.

Inventory leading species stratum	*n*	*Weighted mean volumes net dwb at 12.5cm+ dbh*				*Incremental volume % associated with dead PL (based on Ph II)* ***[B/A*100%]***	*% of Live + Dead PL volume represented by Dead PL (based on Ph II)* ***[B/C*100%]***
		Phase I (inventory) Live all spp	*Phase II (ground) Live all spp* ***[A]***	*Phase II Dead PL* ***[B]***	*Ph II Live all spp + dead PL* ***[C]***		
Spruce	16	218	181	73.535	254.181	41%	29%
Balsam	9	221	186	45.163	231.603	24%	20%
Fir	14	321	200	38.361	238.336	19%	16%
Other	10	186	187	17.444	204.747	9%	9%
All	*49*	*242*	*189*	46.043	234.858	24%	20%

Table 15: Summary of dead PL basal area in the Phase II ground samples.

Inventory leading species stratum	*n*	*Weighted mean basal area/ha at 7.5cm+ dbh*				*Incremental BA % associated with dead PL (based on Ph II)* ***[B/A*100%]***	*% of Live + Dead PL BA represented by Dead PL (based on Ph II)* ***[B/C*100%]***
		Phase I (inventory) Live all spp	*Phase II (ground) Live all spp* ***[A]***	*Phase II Dead PL* ***[B]***	*Ph II Live all spp + dead PL* ***[C]***		
Spruce	16	29.9	24.1	8.9	33.0	36.9%	26.9%
Balsam	9	38.8	28.9	4.5	33.4	15.7%	13.5%
Fir	14	40.8	26.4	4.9	31.3	18.6%	15.7%
Other	10	30.2	24.8	2.2	27.0	8.8%	8.1%
All	*49*	34.8	25.8	5.5	31.3	21.4%	17.6%

4. CONCLUSIONS AND RECOMMENDATIONS

The VDYP7-based VRI statistical analysis for the mature green target population in the eastern portion of the Quesnel TSA suggests that, overall, inventory volumes are overestimated. The sample suggested that the mean Phase I inventory volume was about 28% higher than the mean Phase II ground volume (ratio of means = 0.78). The sampling error for this volume bias estimate was ±15.8% (at the 95% confidence level). The level of precision for the overall volume ratio estimate was reasonable given the relatively small sample size. However, caution is advised when viewing stratum results.

Phase I inventory age was also found to be overestimated in the sample. Mean Phase I ages were about 15% higher than the mean ground sample ages. Inventory basal area/ha also appeared to be overestimated, based on the sample. The sample mean overall Phase I basal area/ha was about 35% higher compared with the mean Phase II basal area (ratio of means = 0.74). The basal area overestimation was particularly dramatic in the Fir leading stratum but with a high sampling error in this stratum, the results must be interpreted cautiously.

There were concerns regarding the photo-interpreted values for basal area/ha and trees/ha in this management unit. As a result, the inventory was processed though the VDYP7 yield model as an F-type inventory standard so that VDYP7 would generate the basal area and trees/ha values internally in the FIPSTART module. When FIPSTART-generated BA and TPH were used in lieu of the photo-estimated values for these attributes, the volume overestimation observed for the sample decreased slightly (ratio of means = 0.81 corresponding with mean Phase I volumes being 23% higher than the mean Phase II ground volumes). The sample also indicated that FIPSTART offered a slight improvement in the overall estimates of BA and Lorey height. No improvement was seen for TPH estimation, on average.

Since basal area is a major driver of volume estimation in the VDYP7 model, it was suspected that the observed volume overestimation in the mature green component of the eastern portion of the Quesnel TSA may be closely related to the overestimation of basal area. This was supported by results of an analysis of the relative contribution of error associated with volume estimation in the VDYP7 model and error associated with input attributes to the volume estimation process.

Based on issues encountered through the statistical analysis in this management unit, the following recommendations are made:

- Investigate the differences between the photo-interpreted and VDYP7-generated estimates of basal area and trees/ha in relation to the ground-based estimates to determine opportunities for improving the Phase I estimates for these attributes, either through changes in photo-estimation methodologies or FIPSTART design.
- Further develop definitions, terminology and graphical displays for the concept of model-related and attribute-related components of volume bias in the inventory.
- Develop a uniform extract from the LRDW for future VRI statistical analyses that provides a complete set of all attributes required for the analysis (including Lorey height, BA and TPH at 7.5cm+ dbh utilization) along with clear definitions (i.e. data dictionary).
- Utilize the Phase II sample data to test the inventory live/dead estimation methodology in management units where the methodology has been applied and Phase II data is available.
- This report is a technical document intended to provide complete details of the analysis. However, it is also recommended that a template for communicating these results in a uniform, succinct format suitable for wider distribution be developed.

5. APPENDIX A: PHASE I INVENTORY ATTRIBUTES

Table A-1: Phase I Input Attributes (unprojected)

SAMPLE	FEATURE_ID	BEC	SAMPLE SELECTION STRATUM	ANALYSIS STRATUM (leading species)	Sample selection weight	inventory_standard	measurement year (for projection)	Reference Year	Input Age sp1	Input Height sp1	Input Age sp2	Input Height sp2	Input CC%	Input BA7.5	Input TPH7.5	Species composition
0001	8277396	IDF	Young	S	5,535	V	2010	2005	100	24	100	31	15	13	310	SX 70 FD 30
0002	7595056	SBPS	Young	S	5,535	V	2010	2007	110	19	80	22	45	31	672	SW 90 AT 10
0003	8158351	SBS	Young	S	5,535	V	2010	2006	102	29.9	99	25	65	48	800	SW 50 FD 20 EP 20 AT 10
0004	7579184	SBS	Young	S	5,535	V	2010	2006	55	17	55	19	45	25	850	SW 50 FD 34 AT 10 EP 5 P 1
0005	7580460	SBS	Young	B	5,535	V	2010	2006	80	21	50	21	50	45	950	BL 60 AC 15 SW 15 AT 5 F 5
0006	7569093	SBS	Young	F	5,486	V	2010	2006	110	19	140	22	40	25	800	FD 70 SW 10 PL 10 AT 10
0007	7598138	SBS	Young	F	5,486	V	2010	2005	110	25	115	25	60	12	220	FD 90 SW 5 AT 5
0008	7570392	SBS	Young	F	5,486	V	2010	2005	70	18	80	19	60	33	1850	FD 80 PL 10 SW 10
0009	7582466	SBS	Young	F	5,486	V	2010	2005	102	37	120	28	45	72	420	FD 75 EP 20 AC 5
0012	7588940	SBS	Young	F	5,486	V	2010	2006	70	21	70	20	40	25	750	FD 60 SW 20 PL 20
0013	7563982	SBS	Old	Dec	5,790	V	2010	2005	115	25	90	25	25	16	215	AT 70 SW 25 PL 5
0014	7565111	SBS	Young	Dec	5,347	V	2010	2006	105	26	130	30	15	6	115	AT 80 SW 15 AC 5
0015	7576440	SBS	Young	Dec	5,347	V	2010	2006	60	18	60	19	45	15	825	EP 50 SW 30 AT 20
0016	7576863	SBS	Young	Dec	5,347	V	2010	2005	100	27			40	35	600	AT 100
0018	7586889	SBS	Young	Dec	5,347	V	2010	2005	65	22	65	23	85	40	1285	AT 50 FD 35 SW 10 EP 5
0019	7586978	SBS	Young	Dec	5,347	V	2010	2005	95	25	95	24	60	40	1000	AT 40 EP 40 SW 20
0021	7565003	SBS	Old	S	4,762	V	2010	2006	130	33	125	30	25	22	170	SW 70 AT 25 PL 5
0022	7567117	ESSF	Old	S	4,762	V	2010	2006	230	23	220	20	50	40	1000	SE 70 BL 30
0023	7567804	IMA	Old	B	4,762	V	2010	2006	200	18	190	21	35	25	500	BL 90 SE 10
0024	7567577	ICH	Old	S	4,762	V	2010	2006	260	32	240	28	50	50	650	SW 45 BL 30 FD 15 CW 10
0025	7568126	ESSF	Old	B	4,762	V	2010	2006	230	25	230	27	50	50	825	BL 80 SE 20
0026	7568686	ICH	Old	S	4,762	V	2010	2006	180	28	200	30	35	30	260	SW 40 FD 20 BL 20 CW 20
0027	8157184	SBS	Old	S	4,762	V	2010	2006	120	24	100	18	35	30	350	SW 65 PL 20 BL 10 AT 5
0028	8157385	SBS	Old	S	4,762	V	2010	2006	146	32.3	122	29	10	8	70	SW 85 BL 15
0029	7581416	SBS	Old	S	4,762	V	2010	2005	115	22	110	21	30	25	400	SW 90 BL 10
0030	7585818	ESSF	Old	B	4,762	V	2010	2006	150	18	150	24	65	40	1350	BL 80 SE 20

Table A-1 Cont'd.

SAMPLE	FEATURE_ID	BEC	SAMPLE SELECTION STRATUM	ANALYSIS STRATUM (leading species)	Sample selection weight	inventory_standard	measurement year (for projection)	Reference Year	Input Age sp1	Input Height sp1	Input Age sp2	Input Height sp2	Input CC%	Input BA7.5	Input TPH7.5	Species composition
0031	7592244	ESSF	Old	S	4,762	V	2010	2005	175	23	160	22	65	45	1100	SE 90 BL 10
0032	7590801	ESSF	Old	S	4,762	V	2010	2006	220	30	200	27	35	30	220	SE 60 BL 40
0033	7591489	ESSF	Old	S	4,762	V	2010	2005	170	30	150	26	10	10	80	SE 50 BL 45 PL 5
0034	7590978	ESSF	Old	B	4,762	V	2010	2005	140	23	145	24	60	50	1100	BL 80 SE 20
0035	7591096	ESSF	Old	S	4,762	V	2010	2005	195	33	185	31	60	56	775	SW 65 BL 30 PL 5
0036	7592747	ESSF	Old	B	4,762	V	2010	2006	170	24	180	25	40	40	675	BL 80 SE 20
0037	7592354	ESSF	Old	B	4,762	V	2010	2006	175	20	185	22	35	20	450	BL 60 SE 40
0038	7592065	SBS	Old	S	4,762	V	2010	2005	170	23	140	17	10	10	130	SX 80 BL 10 AC 10
0039	7592101	ESSF	Old	B	4,762	V	2010	2006	170	18	200	27	35	30	475	BL 65 SE 35
0040	7593406	ESSF	Old	B	4,762	V	2010	2006	185	23	170	22	55	45	875	BL 65 SE 35
0042	7598225	SBS	Old	F	5,191	V	2010	2005	180	29	200	29	10	14	200	FD 80 PL 10 SW 10
0043	8156968	SBS	Old	F	5,191	V	2010	2006	130	25	100	21	15	10	110	FD 65 SW 25 PL 10
0044	7596232	SBS	Old	F	5,191	V	2010	2007	120	34	120	33	60	53	545	FD 60 SW 40
0045	7585188	SBS	Old	F	5,191	V	2010	2005	130	28	130	25	60	45	910	FD 40 SW 40 AT 10 BL 10
0046	7584499	SBS	Old	F	5,191	V	2010	2006	130	34	120	31	70	70	650	FD 70 SW 20 AT 10
0047	7588702	SBS	Old	F	5,191	V	2010	2006	160	35	150	32	70	75	625	FD 70 SW 15 AT 5 EP 5 P 5
0048	7588695	SBS	Old	F	5,191	V	2010	2006	160	34	130	27	55	60	650	FD 60 SW 20 AT 15 EP 5
0049	7582650	SBS	Old	Dec	5,790	V	2010	2005	120	25	100	22	35	25	325	AT 60 EP 25 SW 15
0050	7588472	SBS	Old	Dec	5,790	V	2010	2006	120	30	120	29	55	45	700	AT 60 SW 20 EP 10 FD 5
0052	7573426	SBS	Young	Dec	5,347	V	2010	2006	105	22	105	25	65	35	1150	AT 70 SW 20 FD 10
0053	7596645	SBS	Young	F	5,486	V	2010	2005	80	25	90	23	55	40	835	FD 50 SW 30 AT 20
0054	7576307	SBS	Young	F	5,486	V	2010	2006	100	26	100	24	40	30	625	FD 80 PL 20
0057	7596612	SBS	Young	Dec	5,347	V	2010	2005	90	25	100	27	50	34	850	EP 60 AT 20 SW 20

Table A-2: Phase I Projected Attributes – VRISTART and FIPSTART

SAMPLE	v7_age1 projected to meas yr	v7_ht1 projected to meas yr	v7_age2 projected to meas yr	v7_ht2 projected to meas yr	VRISTART projection				FIPSTART projection			
					VDYP7 basal area/ha (BA) @7.5 projected to meas yr	VDYP7 trees/ha (TPH) @7.5 projected to meas yr	VDYP7 lorey height @7.5 projected to meas yr	VDYP7 vol/ha net dwb @12.5 projected to meas yr (from VRIMS)	VDYP7 basal area/ha (BA) @7.5 projected to meas yr	VDYP7 trees/ha (TPH) @7.5 projected to meas yr	VDYP7 lorey height @7.5 projected to meas yr	VDYP7 vol/ha net dwb @12.5 projected to meas yr (from VRIMS)
0001	105	25	105	32	13.7	307	24.4	108.9	19.6	471	22.7	148.3
0002	113	20	83	22	31.8	664	16.7	156.3	24.7	881	16.2	117.5
0003	106	31	103	26	48.7	763	25.6	399.4	39.2	804	26.5	345.4
0004	59	18	59	20	28.0	855	17.4	140.7	24.5	1210	16.4	109.4
0005	84	22	54	22	47.7	943	19.4	272.3	31.7	947	19.6	187.6
0006	114	19	144	23	25.6	778	16.7	120.5	23.6	814	16.5	108.5
0007	115	26	120	26	13.2	227	24	94.4	36.6	796	21.4	232.7
0008	75	19	85	20	35.1	1791	15.4	140.0	27.4	1211	15.5	116.2
0009	107	38	125	28	72.0	420	32.6	670.3	39.6	424	33.1	410.3
0012	74	22	74	21	26.4	731	19.2	160.2	28.6	965	18.7	166.8
0013	120	25	95	26	16.6	207	24.4	100.7	27.9	499	23.2	163.6
0014	109	26	134	31	6.6	120	26.1	41.9	23.7	359	24.5	141.8
0015	64	19	64	20	17.1	857	18.3	78.7	21.8	921	17.6	105.4
0016	105	28			36.4	561	24.8	207.7	31.9	493	25.5	191
0018	70	23	70	24	42.9	1222	20.9	244.1	35.5	1263	21.3	205
0019	100	26	100	25	41.1	935	23.3	266.0	31.6	781	21.7	192.8
0021	134	33	129	30	22.0	170	30.7	205.7	38.6	459	29.8	364.3
0022	234	23	224	20	39.9	997	18	234.9	34.2	811	19.2	216.7
0023	204	18	194	21	25.0	501	14.7	103.5	29.1	888	14.4	120.8
0024	264	32	244	28	49.9	647	26.8	406.8	46.6	641	26.3	361.7
0025	234	25	234	27	50.0	824	20.6	318.7	40.0	807	20.9	264.8
0026	184	28	204	30	30.0	261	24	196.0	42.7	730	22.8	285.4
0027	124	25	104	18	30.4	339	21	198.5	32.0	779	21.2	229.5
0028	150	33	126	29	8.1	70	30	78.9	26.8	336	28.8	259.6
0029	120	23	115	22	25.4	385	19.5	158.1	27.0	714	19	170

Table A-2 Cont'd.

SAMPLE	v7_age1 projected to meas yr	v7_ht1 projected to meas yr	v7_age2 projected to meas yr	v7_ht2 projected to meas yr	VRISTART projection				FIPSTART projection			
					VDYP7 basal area/ha (BA) @7.5 projected to meas yr	VDYP7 trees/ha (TPH) @7.5 projected to meas yr	VDYP7 lorey height @7.5 projected to meas yr	VDYP7 vol/ha net dwb @12.5 projected to meas yr (from VRIMS)	VDYP7 basal area/ha (BA) @7.5 projected to meas yr	VDYP7 trees/ha (TPH) @7.5 projected to meas yr	VDYP7 lorey height @7.5 projected to meas yr	VDYP7 vol/ha net dwb @12.5 projected to meas yr (from VRIMS)
0030	154	18	154	24	40.5	1326	15.6	190.7	36.4	1332	14.4	157.4
0031	180	23	165	22	44.6	1094	18.6	280.0	37.4	978	18.7	236.7
0032	224	30	204	27	30.0	220	26.6	246.0	36.5	541	25	296.4
0033	175	30	155	26	10.0	81	26.1	81.4	27.4	397	24.9	221.5
0034	145	24	150	25	50.4	1067	19.1	302.8	41.0	1050	19	248.2
0035	200	33	190	31	55.8	770	28.1	541.4	45.3	658	27.6	422.4
0036	174	24	184	25	39.8	674	19.6	242.8	36.2	799	20	231.7
0037	179	20	189	22	20.0	453	18.2	116.0	28.8	838	17.6	161.1
0038	175	24	145	18	10.3	136	21.5	67.2	20.1	425	20.6	128.7
0039	174	18	204	27	29.7	479	18.8	169.1	26.7	904	15.5	127.6
0040	189	23	174	22	44.9	874	18.9	269.0	37.6	943	19.7	239.3
0042	185	29	205	29	14.5	206	27.1	123.0	28.1	365	26.1	224.8
0043	134	25	104	22	10.3	110	23	70.5	25.3	505	22.3	178.2
0044	123	34	123	33	53.5	529	31	533.5	48.2	719	29.6	473.3
0045	135	29	135	26	45.7	881	23.4	327.2	39.8	820	24.1	297.6
0046	134	35	124	32	70.6	630	30.1	634.3	48.3	684	29.7	448.2
0047	164	35	154	32	74.7	619	30.3	674.0	46.4	621	30.3	441.1
0048	164	34	134	28	59.8	637	28.1	480.8	44.6	584	29.5	389.4
0049	125	25	105	23	25.3	309	23.2	139.7	27.8	599	22.3	153
0050	124	30	124	30	45.5	664	27.5	321.3	39.7	610	26.9	279.6
0052	109	22	109	26	36.1	1101	21.1	178.6	33.8	938	20.3	161.8
0053	85	26	95	24	41.8	798	22.2	276.7	36.8	929	22.1	246.9
0054	104	27	104	24	30.8	603	22.6	221.5	35.2	713	22.7	255
0057	95	26	105	28	34.9	801	25	278.7	27.1	613	25.3	223.6

6. APPENDIX B: PHASE II COMPILED GROUND ATTRIBUTES

Table B-1: Phase II (ground) compiled attributes.

SAMPLE	Species composition @4cm+dbh	Basal area/ha @7.5cm+dbh	DEAD PL Basal area/ha @7.5cm+dbh	Trees/ha @7.5cm+dbh	Lorey height @7.5cm+dbh (ht_mean1)	Live Vol/ha with NVAF net dwb (NVL_NWB) @12.5cm+dbh	DEAD PL vol/ha net dwb @12.5cm+dbh
0001	Sx 60 Fd 20 At 20	5	36.0	278	19.5	24.7	236.1
0002	Sw 65 At 30 Ac 05	23	3.0	698	16.2	147.2	18.2
0003	Sx 57 Fd 29 At 14	28	16.8	994	21.6	180.3	138.8
0004	Fd 73 Sw 27	20		991	11.7	89.0	
0005	Bl 84 Sw 11 At 05	26.6		714	20.6	170.8	
0006	Fd 73 Pl 18 At 09	11	10.0	564	16.7	45.0	53.6
0007	Fd 71 Sx 18 At 06 Pl 05	23.8	7.0	770	15.4	146.4	38.1
0008	Fd 86 Sx 14	19.6		557	20.5	119.4	
0009	Fd 67 Sx 15 At 11 Ep 07	36.4		723	28.0	311.0	
0012	Fd 58 Bl 33 Sw 09	16.2	21.6	317	20.3	115.6	175.9
0013	At 53 Sx 29 Pl 06 Ac 06 Fd 06	15	10.0	433	20.7	99.6	78.1
0014	Sw 25 At 25 Fd 25 Ac 25	5.6	8.4	20	36.0	62.7	76.3
0015	Sx 38 At 25 Ac 25 Bl 08 Ep 04	33.6		723	26.1	242.5	
0016	At 75 Ep 17 Ac 08	21.6	1.8	200	26.7	171.0	17.9
0018	Sx 42 Ep 37 Fd 16 Bl 05	25.2		1141	19.3	137.5	
0019	At 59 Sw 33 Ac 08	37.8		348	28.2	331.9	
0021	Sx 95 Ac 05	26.6	4.2	96	41.2	311.7	44.2
0022	Bl 67 Se 33	33.6		863	21.4	237.3	
0023	Bl 100	37.8		1533	16.2	205.2	
0024	Cw 85 Sx 12 Bl 03	55.8		653	31.7	407.4	
0025	Se 69 Bl 31	28.8		581	16.3	218.2	
0026	Bl 64 Sx 14 Fd 14 Cw 08	23.4	7.2	534	21.9	152.5	58.4
0027	Sx 80 Pl 20	6.25	16.3	299	14.8	34.2	120.1
0028	Sx 70 Bl 30	18	14.4	1177	16.5	91.5	126.8
0029	Sx 80 At 10 Bl 07 Fd 03	36.4	7.0	292	20.8	357.1	80.5
0030	Se 55 Bl 45	40.6		905	26.0	320.1	
0031	Bl 67 Sw 33	36		872	13.8	254.6	
0032	Se 95 Bl 05	30.8	2.8	217	21.5	305.3	35.1
0033	Bl 71 Se 29	8.4	29.4	824	11.9	29.3	276.3
0034	Bl 80 Se 20	34.2		924	22.0	254.3	
0035	Se 82 Bl 18	18	1.8	228	20.8	181.4	26.0
0036	Bl 87 Se 13	27		386	18.1	196.3	
0037	Bl 97 Sw 03	25	5.0	1564	9.0	91.3	41.1
0038	Bl 57 Sx 43	19.6		343	18.1	132.4	
0039	Bl 65 Sw 35	16.8	36.4	1716	7.4	37.8	372.7
0040	Sw 85 Bl 15	23.4		344	20.1	186.5	
0042	Fd 57 Sx 25 At 18	35		896	20.4	231.0	
0043	At 44 Fd 33 Pl 11 Sx 12	12.6	21.0	274	22.7	94.0	177.4
0044	Sw 64 Fd 18 Bl 18	37.8		736	31.3	337.7	

Table B-1 cont'd.

SAMPLE	Species composition @4cm+dbh	Basal area/ha @7.5cm+dbh	DEAD PL Basal area/ha @7.5cm+dbh	Trees/ha @7.5cm+dbh	Lorey height @7.5cm+dbh (ht_mean1)	Live Vol/ha with NVAF net dwb (NVL_NWB) @12.5cm+dbh	DEAD PL vol/ha net dwb @12.5cm+dbh
0045	Sx 80 Ep 20	7.2	3.6	49	31.1	72.5	35.5
0046	Fd 81 Sx 19	37.8	5.4	459	35.8	333.3	56.6
0047	Fd 40 Sx 36 Ep 24	35		412	27.1	296.0	
0048	Sx 58 At 33 Fd 09	16.8		328	29.4	134.8	
0049	At 88 Sx 12	17		319	26.5	133.0	
0050	At 39 Fd 28 Sw 22 Ep 11	45		865	29.1	337.0	
0052	Fd 46 Sx 31 At 23	36.4	1.4	674	23.9	273.4	0.0
0053	Sx 58 Ep 19 Fd 13 At 10	43.4		896	20.3	309.8	
0054	Fd 85 Sx 12 Ep 03	36.4		915	24.4	258.5	
0057	At 64 Sx 27 Fd 09	11		119	23.4	83.8	

7. APPENDIX C: POTENTIAL PHASE I BA "OUTLIERS"

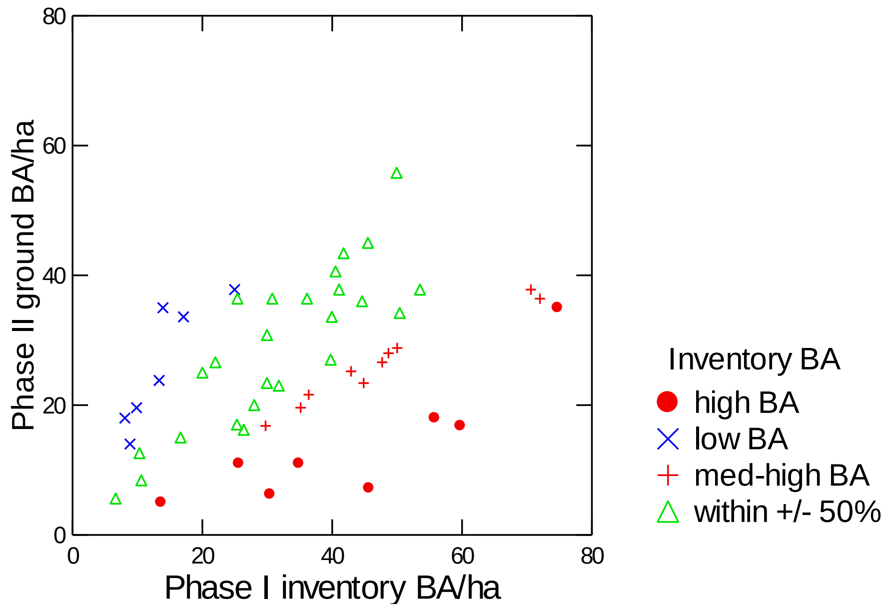

Figure C-1: Ground vs. inventory BA/ha (at 7.5cm+ dbh). The colour coding is based on the ratio of Phase II/Phase I BA. A ratio of ≥1.5 corresponds with "low inventory BA"; ≤0.5 with "high inventory BA"; <0.6 but >0.5 as "medium-high inventory BA". The Δ samples are between these outside ranges.

The samples corresponding to the points identified on the graph above are provided in the tables below. They have been categorized (LOW and HIGH inventory ba/ha) and sorted by the ratio of Phase II to Phase I BA ratio (hence the samples higher on the lists show a greater relative difference between the inventory and the ground sample basal area).

Table 1: Sample with relatively LOW PHASE I INVENTORY BA/HA.

SAMPLE	*Ph I lead spp*	*Ph I BA7.5*	*Ph II BA7.5*	*Ph I vol/ha (12.5 net dwb)*	*Ph II vol/ha (12.5 net dwb)*	*Ph II deal PL vol/ha*	*Ratio of Ph II BA / Ph I BA*	*Ratio of Ph II vol / Ph I vol*
42	FDI	13.9	35	123.0	231.0	0	2.512	1.878
28	SW	8.1	18	78.9	91.5	126.8	2.231	1.159
38	SX	9.9	19.6	67.2	132.4	0	1.985	1.972
15	EP	17.1	33.6	78.7	242.5	0	1.966	3.08
7	FDI	13.3	23.8	94.4	146.4	38.1	1.783	1.55
23	BL	25.0	37.8	103.5	205.2	0	1.514	1.983

Table 2: Sample with relatively HIGH PHASE I INVENTORY BA/HA.

SAMPLE	*Ph I lead spp*	*Ph I BA7.5*	*Ph II BA7.5*	*Ph I vol/ha (12.5 net dwb)*	*Ph II vol/ha (12.5 net dwb)*	*Ph II deal PL vol/ha*	*Ratio of Ph II BA / Ph I BA*	*Ratio of Ph II vol / Ph I vol*
45	FDI	45.7	7.2	327.2	72.5	35.5	0.158	0.221
27	SW	30.4	6.3	198.5	34.2	120.1	0.205	0.172
48	FDI	59.8	16.8	480.8	134.8	0	0.281	0.28
57	EP	34.9	11.0	278.7	83.8	0	0.315	0.301
35	SW	55.8	18.0	541.4	181.4	26	0.323	0.335
1	SX	13.7	5.0	108.9	24.7	236.1	0.366	0.227
6	FDI	25.6	11.0	120.5	45.0	53.6	0.429	0.374
47	FDI	74.7	35.0	674.0	296.0	0	0.468	0.439
9	FD	72.0	36.4	670.3	311.0	0	0.506	0.464
40	BL	44.9	23.4	269.0	186.5	0	0.522	0.693
46	FDI	70.6	37.8	634.3	333.3	56.6	0.535	0.525
5	BL	47.7	26.6	272.3	170.8	0	0.558	0.627
8	FDI	35.1	19.6	140.0	119.4	0	0.558	0.853
39	BL	29.7	16.8	169.1	37.8	372.7	0.565	0.223
3	SW	48.7	28.0	399.4	180.3	138.8	0.575	0.451
25	BL	50.0	28.8	318.7	218.2	0	0.576	0.685
18	AT	42.9	25.2	244.1	137.5	0	0.587	0.563
16	AT	36.4	21.6	207.7	171.0	17.9	0.594	0.823

8. APPENDIX D: HEIGHT AND AGE MATCHING

The current standard for Phase II ground age and height is based on the average of the T, L, S, X and O trees. The matching typology is as follows:

Case 1: Phase I leading species matches the Phase II leading species at the Sp0 level

Case 2: Phase I second species matches the Phase II leading species at the Sp0 level

Case 3: Phase I leading species matches the Phase II leading species on a conifer-to-conifer (or deciduous-to deciduous) basis

Case 4: Phase I second species matches the Phase II leading species on a conifer-to-conifer (or deciduous-to deciduous) basis

Case 5: No match

Table D-1: Phase I and II heights and ages for ratio comparison

SAMPLE	Phase II (ground) lead spp @ 4cm+dbh	Ph II lead species age (aget_tlsxo)	Ph II lead species hei ght (ht_tlsxo)	Number of age trees (n_ag_tlsxo)	Number of height trees (n_ht_tlsxo)	Ph I inventory lead SP01	Ph I inventory second SP02	Case for match	Ph I age for match (depending on case; msg if case 5)	Ph I ht for match (depending on case; msg if case 5)
0001	SX	99	20.4	2	2	SX	FD	1	105	25
0002	SW	102	23.24	5	5	SW	AT	1	113	20
0003	SX	90	24.34	5	5	SW	FDI	1	106	31
0004	FD	91	15.14	5	5	SW	FDI	2	59	20
0005	BL	85	19.94	5	5	BL	ACT	1	84	22
0006	FD	49	17.72	5	5	FDI	SW	1	114	19
0007	FD	112	20.88	5	5	FDI	SW	1	115	26
0008	FD	85	20.1	5	5	FDI	PLI	1	75	19
0009	FD	94	33.08	5	5	FD	EP	1	107	38
0012	FD	108	30	5	5	FDI	SW	1	74	22
0013	AT	91	26.88	5	5	AT	SW	1	120	25
0014	AT	76	30.4	2	2	AT	SW	1	109	26
0015	SX	52	21.98	5	5	EP	SW	2	64	20
0016	AT	98	30.66	5	5	AT		1	105	28
0018	SX	143	26.16	5	5	AT	FDI	4	70	24
0019	AT	99	29.96	5	5	AT	EP	1	100	26
0021	SX	119	38.52	5	5	SW	AT	1	134	33
0022	BL	160	19.68	5	5	SE	BL	2	224	20
0023	BL	144	17.28	5	5	BL	SE	1	204	18
0024	CW	214	35.62	5	5	SW	BL	3	264	32
0025	SE	208	23	5	5	BL	SE	2	234	27
0026	BL	194	20.55	4	4	SW	FDI	3	184	28
0027	SX	72	19	3	3	SW	PLI	1	124	25
0028	SX	127	25.48	5	5	SW	BL	1	150	33
0029	SX	103	30.52	5	5	SW	BL	1	120	23
0030	SE	149	27.06	5	5	BL	SE	2	154	24

Table D-1 cont'd.

SAMPLE	Phase II (ground) lead spp @ 4cm+dbh	Ph II lead species age (aget_tlsxo)	Ph II lead species hei ght (ht_tlsxo)	Number of age trees (n_ag_tlsxo)	Number of height trees (n_ht_tlsxo)	Ph I inventory lead SP01	Ph I inventory second SP02	Case for match	Ph I age for match (depending on case; msg if case 5)	Ph I ht for match (depending on case; msg if case 5)
0031	BL	141	20.56	5	5	SE	BL	2	165	22
0032	SE	197	31.62	5	5	SE	BL	1	224	30
0033	BL	107	19.86	5	5	SE	BL	2	155	26
0034	BL	127	21.5	5	5	BL	SE	1	145	24
0035	SE	208	34.76	5	5	SW	BL	1	200	33
0036	BL	169	21.6	5	5	BL	SE	1	174	24
0037	BL	172	13.4	5	5	BL	SE	1	179	20
0038	BL	96	19.42	5	5	SX	BL	2	145	18
0039	BL	132	14.28	5	5	BL	SE	1	174	18
0040	SW	174	24.45	4	4	BL	SE	2	174	22
0042	FD	99	23.76	5	5	FDI	PLI	1	185	29
0043	AT	125	23.15	2	2	FDI	SW	5	.	.
0044	SW	126	34.4	6	6	FDI	SW	2	123	33
0045	SX	125	28.9	5	5	FDI	SW	2	135	26
0046	FD	134	39.26	5	5	FDI	SW	1	134	35
0047	FD	122	39.3	3	3	FDI	SW	1	164	35
0048	SX	83	26.08	5	5	FDI	SW	2	134	28
0049	AT	101	31.46	6	5	AT	EP	1	125	25
0050	AT	79	28.83	3	3	AT	SW	1	124	30
0052	FD	100	26.68	5	5	AT	SW	4	109	26
0053	SX	64	21.92	5	5	FDI	SW	2	95	24
0054	FD	103	28.26	5	5	FDI	PLI	1	104	27
0057	AT	100	23.74	5	5	EP	AT	2	105	28

9. APPENDIX E: LEADING SPECIES COMPARISON

Table E-1 to E-3 below summarizes the correspondence between the leading species on the Phase I inventory files and the leading species from the Phase II ground sample compilation. For just over 60% of the samples (30 out of 49), the inventory and the ground sample had the same leading species.

Table E-1: Phase II ground vs. Phase I inventory leading species cross-tabulation, based on the target population in the eastern portion of the Quesnel TSA.

Phase I Inventory leading spp	Phase II Ground leading species at 4cm+ dbh utilization					
	AT	B	CW	FD	S (Se/Sw/Sx)	Total
AT	6	0	0	1	1	8
B	0	6	0	0	3	9
EP	1	0	0	0	1	2
FD	1	0	0	9	4	14
S (Se/Sw/Sx)	0	5	1	1	9	16
Total	8	11	1	11	18	49

Table E-2: Phase II ground vs. Phase I inventory leading species cross-tabulation (Table E-1), where each cell is expressed as a percent of the row (Phase I) total.

Phase I Inventory leading spp	Phase II Ground leading species at 4cm+ dbh utilization						
	AT	B	CW	FD	S (Se/Sw/Sx)	Total %	Total count
AT	75%	0%	0%	12.5%	12.5%	100%	8
B	0%	66.7%	0%	0%	33.3%	100%	9
EP	50%	0%	0%	0%	50%	100%	2
FD	7.1%	0%	0%	64.3%	28.6%	100%	14
S (Se/Sw/Sx)	0%	31.25%	6.25%	6.25%	56.25%	100%	16
Total %	16.3%	22.4%	2.0%	22.4%	36.7%	100%	
Total count	8	11	1	11	18		49

Table E-3: Phase II ground vs. Phase I inventory leading species cross-tabulation (Table E-1), where each cell is expressed as a percent of the column (Phase II) total.

Phase I Inventory leading spp	Phase II Ground leading species at 4cm+ dbh utilization						
	AT	B	CW	FD	S (Se/Sw/Sx)	Total %	Total count
AT	75%	0%	0%	9.1%	5.6%	16.3%	8
B	0%	54.5%	0%	0%	16.7%	18.4%	9
EP	12.5%	0%	0%	0%	5.6%	4.1%	2
FD	12.5%	0%	0%	81.8%	22.2%	28.6%	14
S (Se/Sw/Sx)	0%	45.5%	100%	9.1%	50%	32.7%	16
Total %	100%	100%	100%	100%	100%	100%	
Total count	8	11	1	11	18		49

10. APPENDIX F: SCATTERPLOTS AND RESIDUALS FOR VRISTART ANALYSIS

(NOTE: symbols on graphs correspond with the inventory age of the sample in 2009 i.e. × = "young" 48-120 years and ○ = "old" >120 years)

Spruce leading stratum (Note: RESIDUAL = Phase II value – ratio-adjusted Phase I value)

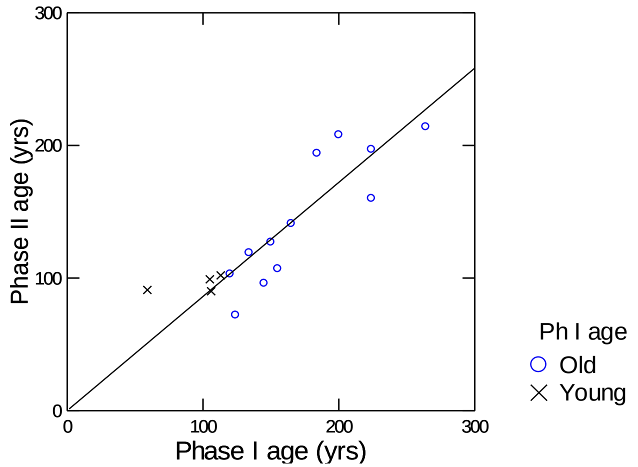

Fig F-1a: Phase II vs. Phase I age. The black line represents the ratio of means.

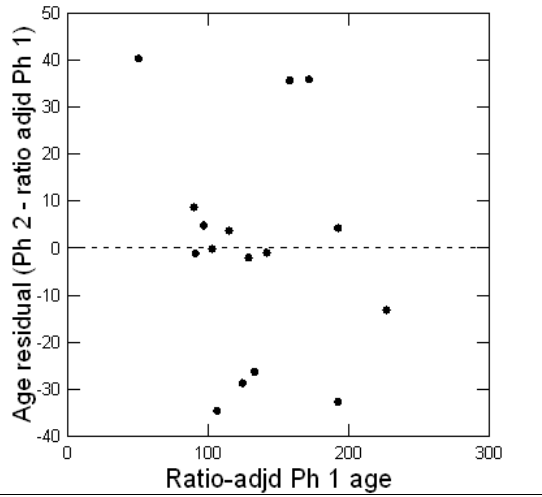

Fig F-1b: Age residuals vs adjusted Phase I inventory age (i.e. R × unadjusted Ph I age).

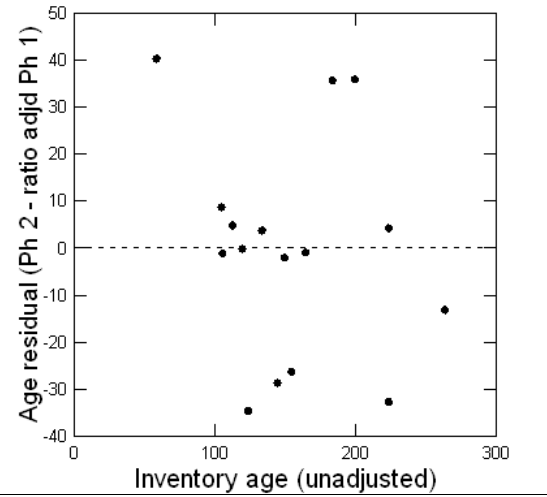

Fig F-1c: Age residuals vs unadjusted Phase I inventory age.

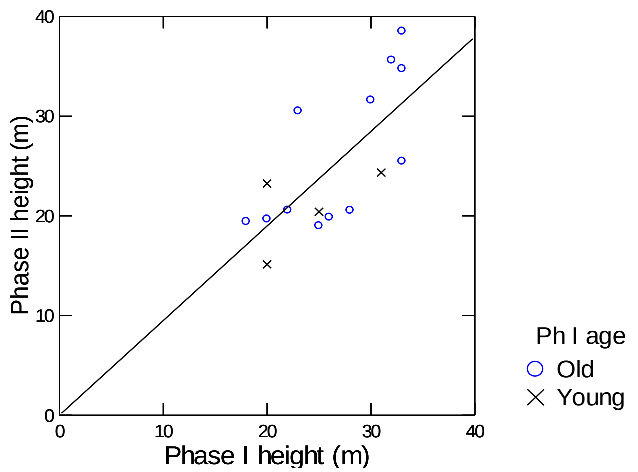

Fig F-2a: Phase II vs. Phase I height. The black line represents the ratio of means.

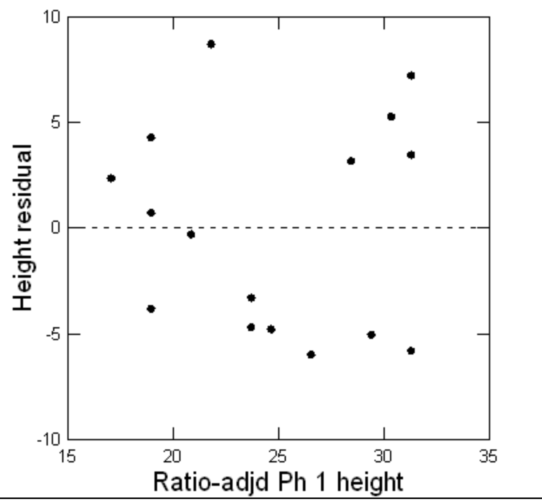

Fig F-2b: Height residuals vs adjusted Phase I inventory height (i.e. R × unadjusted Ph I height).

Fig F-2c: Height residuals vs unadjusted Phase I inventory age.

Spruce leading stratum VRISTART *(Note: RESIDUAL = Phase II value – ratio-adjusted Phase I value)*

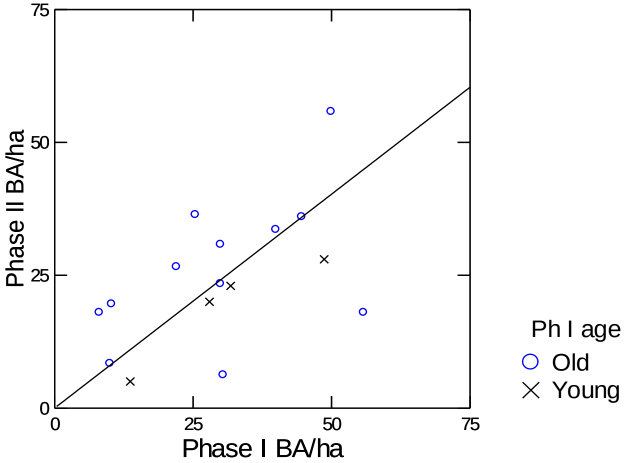

Fig F-3a: Phase II vs. Phase I ba/ha. The black line represents the ratio of means.

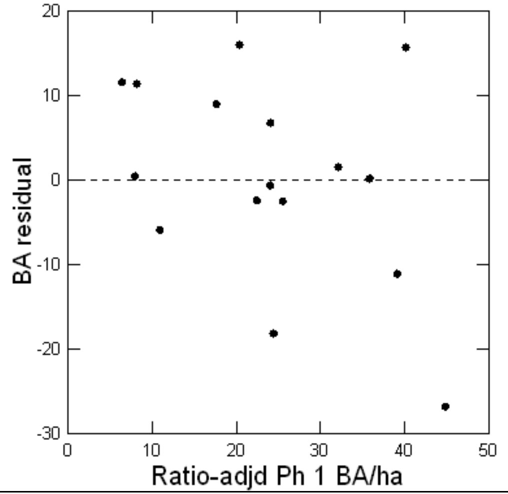

Fig F-3b: Ba/ha residuals vs adjusted Phase I inventory ba/ha (i.e. R × unadjusted Ph I ba/ha).

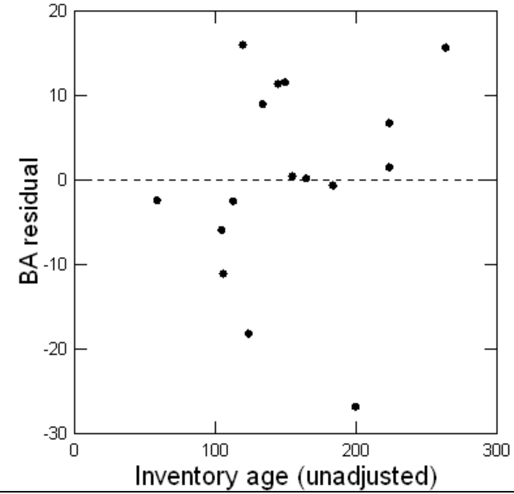

Fig F-3c: Ba/ha residuals vs unadjusted Phase I inventory age.

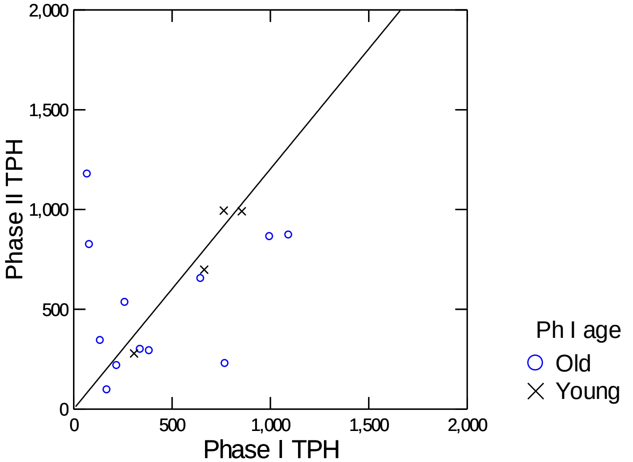

Fig F-4a: Phase II vs. Phase I trees/ha. The black line represents the ratio of means.

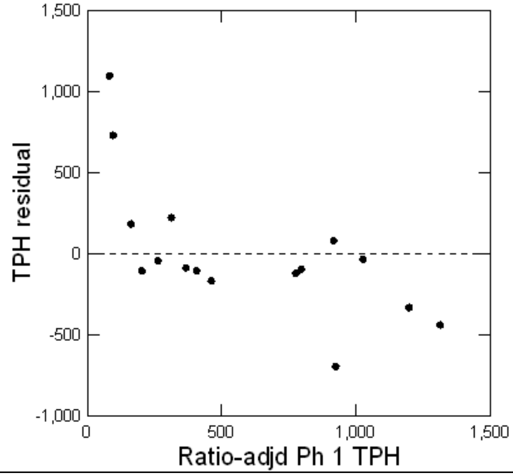

Fig F-4b: Trees/ha residuals vs adjusted Phase I inventory trees /ha (i.e. R × unadjusted Ph I trees /ha).

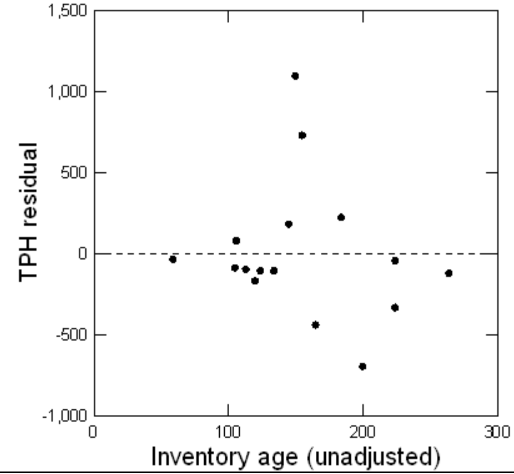

Fig F-4c: Trees /ha residuals vs unadjusted Phase I inventory age.

Spruce leading stratum VRISTART *(Note: RESIDUAL = Phase II value – ratio-adjusted Phase I value)*

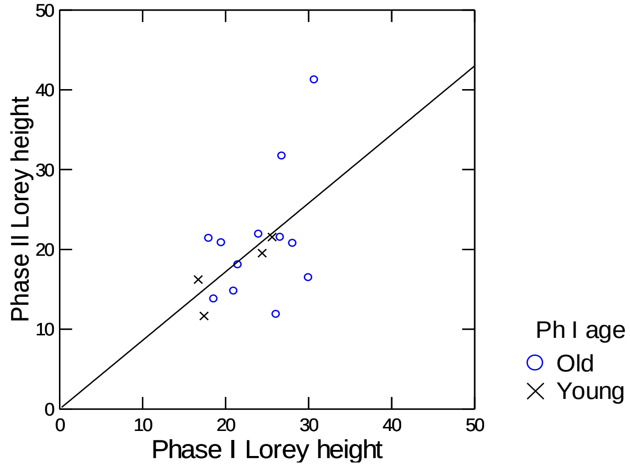

Fig F-5a: Phase II vs. Phase I Lorey height. The black line represents the ratio of means.

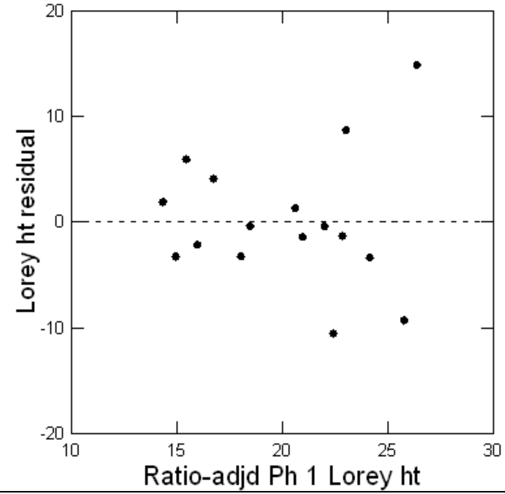

Fig F-5b: Lorey height residuals vs adjusted Phase I inventory Lorey ht (i.e. R × unadjusted Ph I Lorey ht).

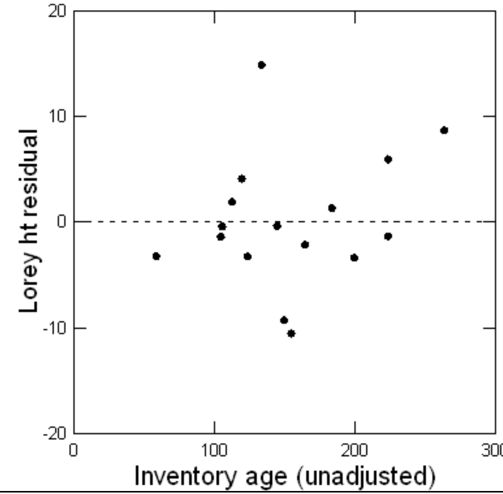

Fig F-5c: Lorey height residuals vs unadjusted Phase I inventory age.

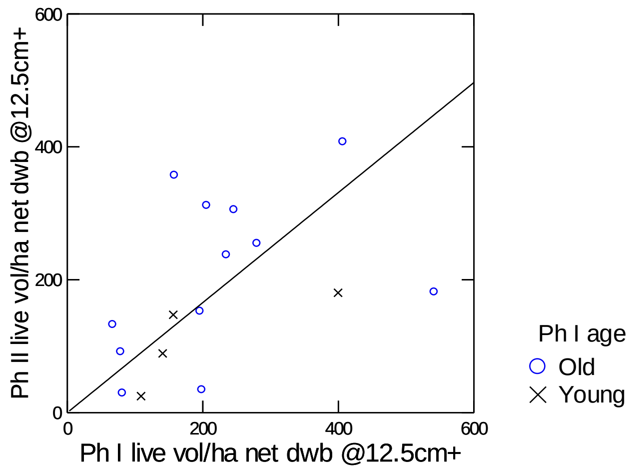

Fig F-6a: Phase II vs. Phase I vol/ha. The black line represents the ratio of means.

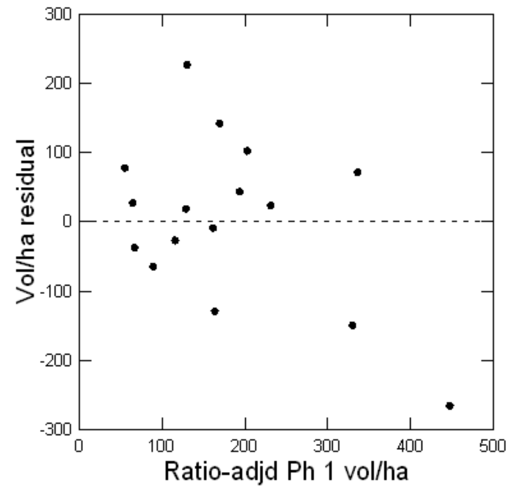

Fig F-6b: Vol/ha residuals vs adjusted Phase I inventory vol/ha (i.e. R × unadjusted Ph I vol/ha).

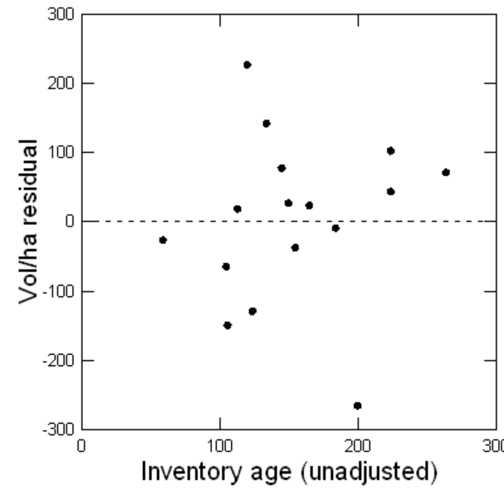

Fig F-6c: Vol/ha residuals vs unadjusted Phase I inventory age.

Balsam leading stratum *(Note: RESIDUAL = Phase II value – ratio-adjusted Phase I value)*

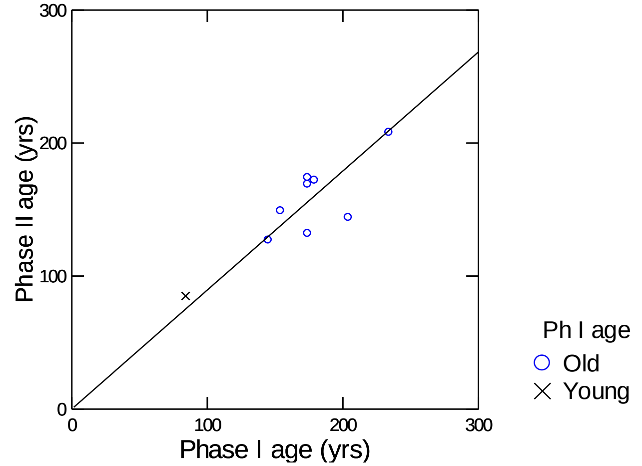

Fig F-7a: Phase II vs. Phase I age. The black line represents the ratio of means.

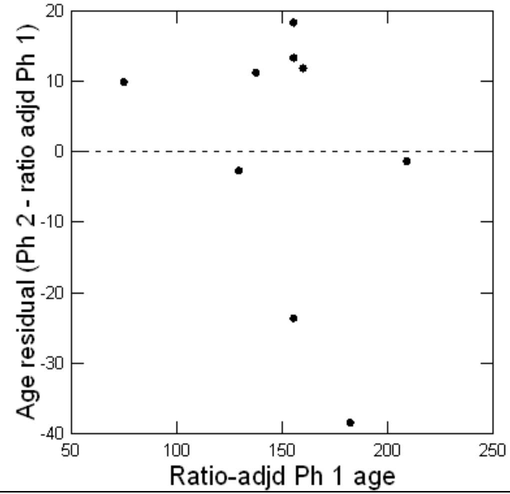

Fig F-7b: Age residuals vs adjusted Phase I inventory age (i.e. R × unadjusted Ph I age).

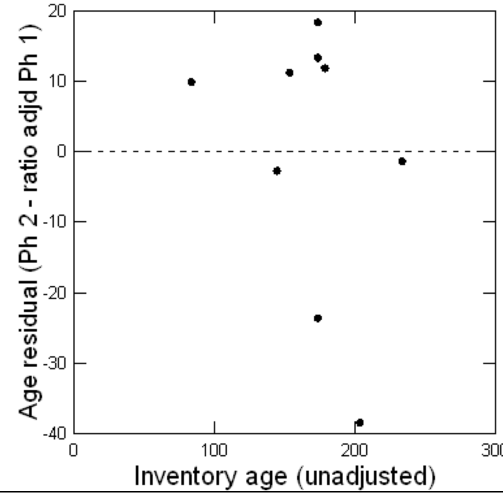

Fig F-7c: Age residuals vs unadjusted Phase I inventory age.

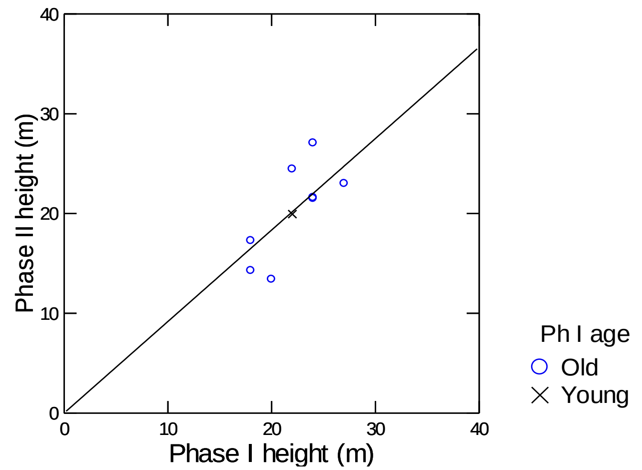

Fig F-8a: Phase II vs. Phase I height. The black line represents the ratio of means.

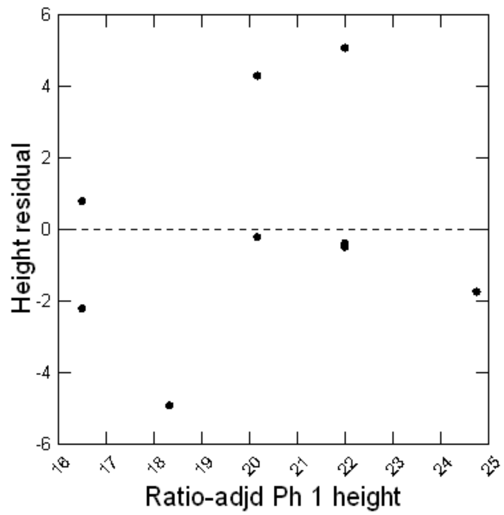

Fig F-8b: Height residuals vs adjusted Phase I inventory height (i.e. R × unadjusted Ph I height).

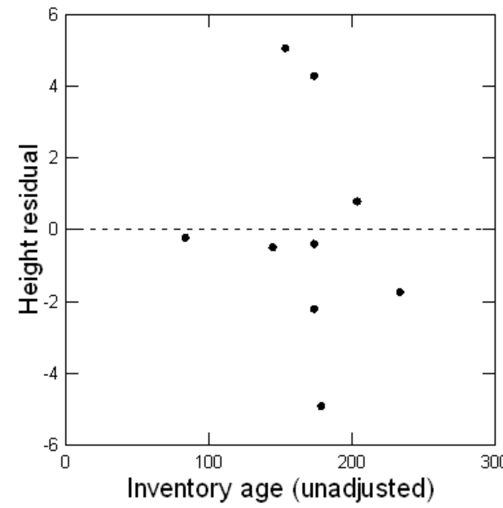

Fig F-8c: Height residuals vs unadjusted Phase I inventory age.

Balsam leading stratum VRISTART (Note: RESIDUAL = Phase II value – ratio-adjusted Phase I value)

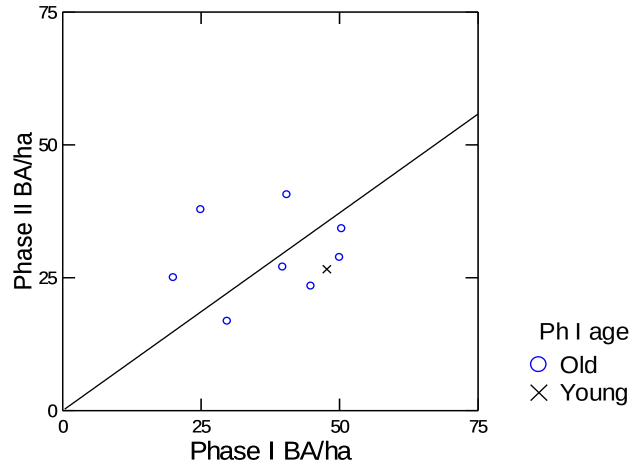

Fig F-9a: Phase II vs. Phase I ba/ha. The black line represents the ratio of means.

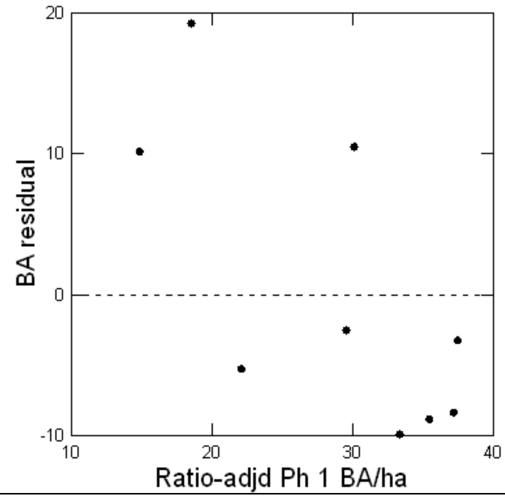

Fig F-9b: Ba/ha residuals vs adjusted Phase I inventory ba/ha (i.e. R × unadjusted Ph I ba/ha).

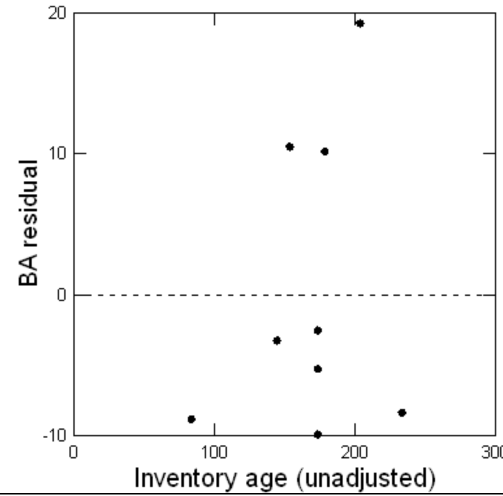

Fig F-9c: Ba/ha residuals vs unadjusted Phase I inventory age.

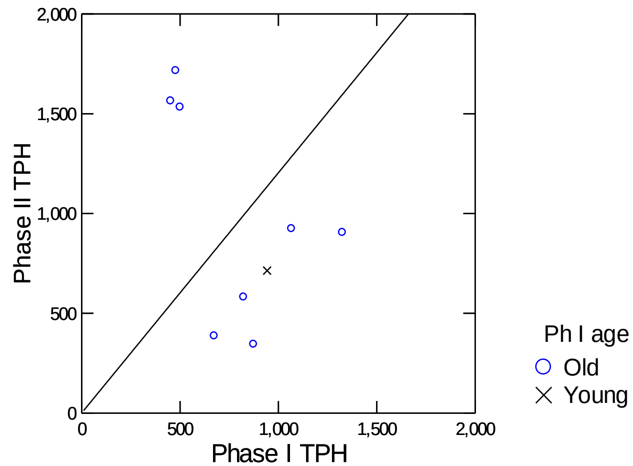

Fig F-10a: Phase II vs. Phase I trees/ha. The black line represents the ratio of means.

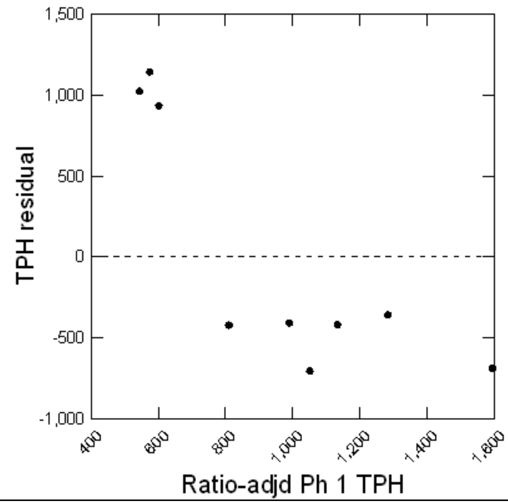

Fig F-10b: Trees/ha residuals vs adjusted Phase I inventory trees /ha (i.e. R × unadjusted Ph I trees /ha).

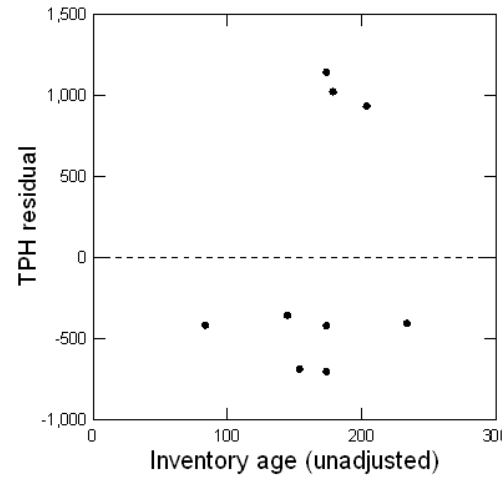

Fig F-10c: Trees /ha residuals vs unadjusted Phase I inventory age.

Balsam leading stratum VRISTART *(Note: RESIDUAL = Phase II value – ratio-adjusted Phase I value)*

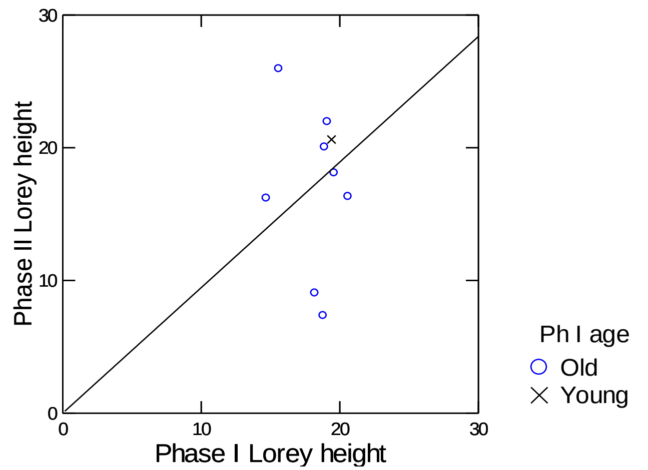

Fig F-11a: Phase II vs. Phase I Lorey height. The black line represents the ratio of means.

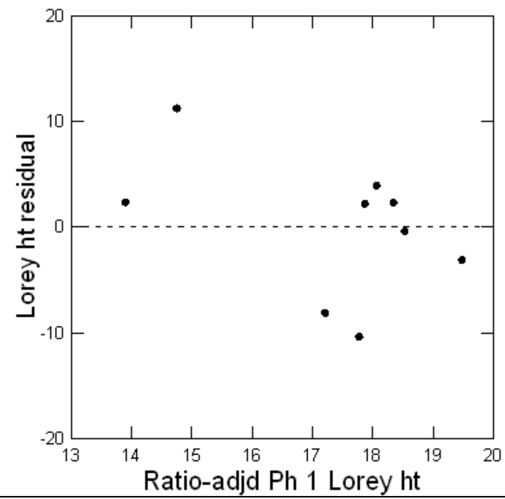

Fig F-11b: Lorey height residuals vs adjusted Phase I inventory Lorey height (i.e. R × unadjusted Ph I Lorey height).

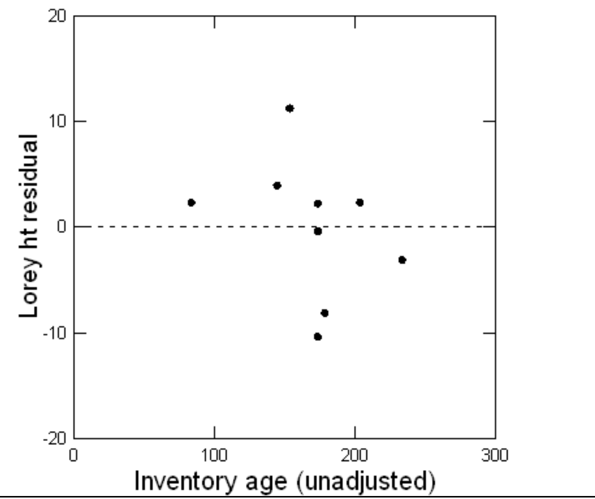

Fig F-11c: Lorey height residuals vs unadjusted Phase I inventory age.

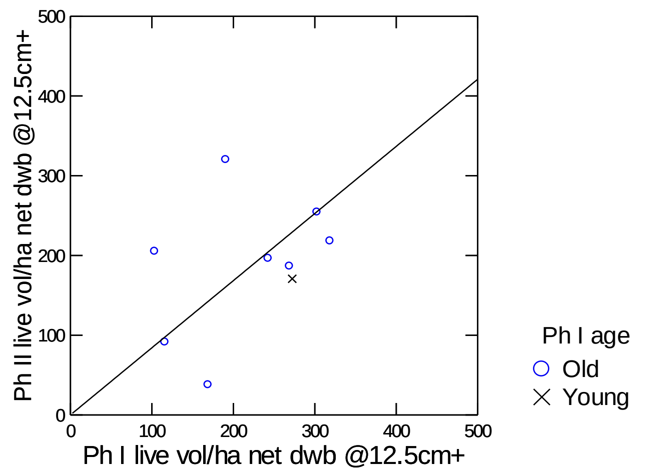

Fig F-12a: Phase II vs. Phase I vol/ha. The black line represents the ratio of means.

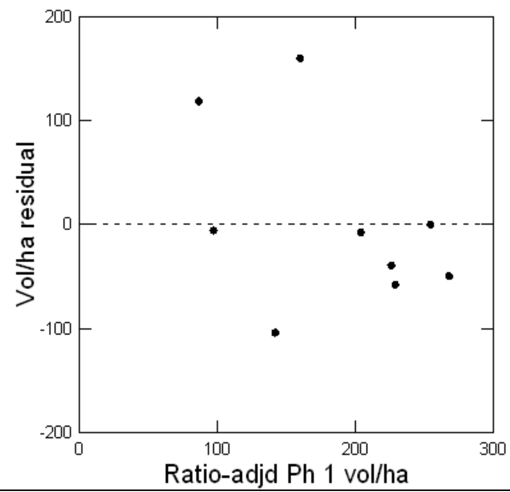

Fig F-12b: Vol/ha residuals vs adjusted Phase I inventory vol/ha (i.e. R × unadjusted Ph I vol/ha).

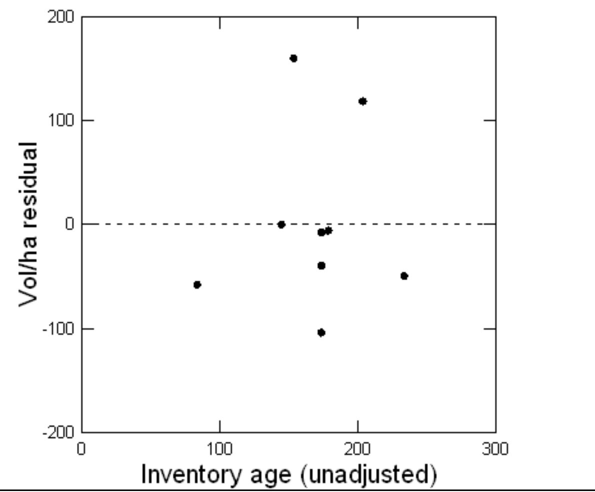

Fig F-12c: Vol/ha residuals vs unadjusted Phase I inventory age.

Fir leading stratum *(Note: RESIDUAL = Phase II value – ratio-adjusted Phase I value)*

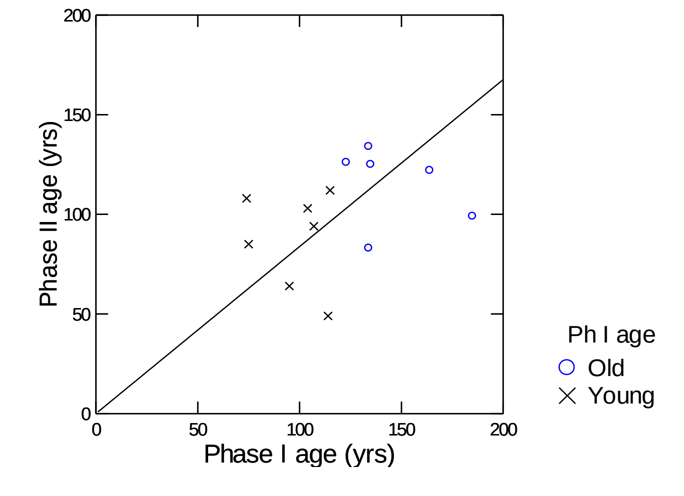

Fig F-13a: Phase II vs. Phase I age. The black line represents the ratio of means.

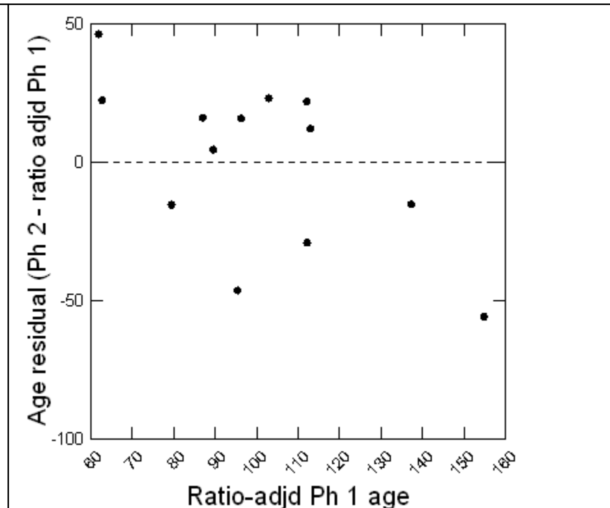

Fig F-13b: Age residuals vs adjusted Phase I inventory ba/ha (i.e. R × unadjusted Ph I ba/ha).

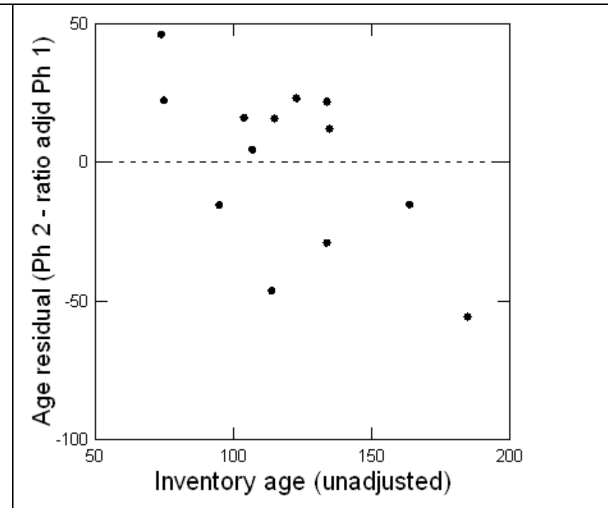

Fig F-13c: Ba/ha residuals vs unadjusted Phase I inventory age.

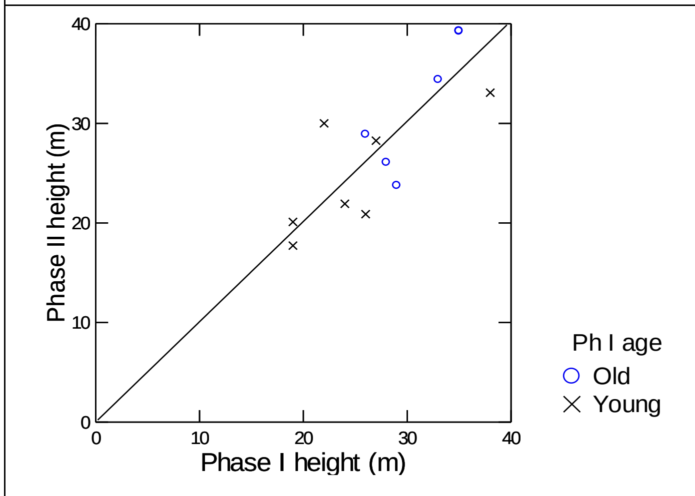

Fig F-14a: Phase II vs. Phase I height. The black line represents the ratio of means.

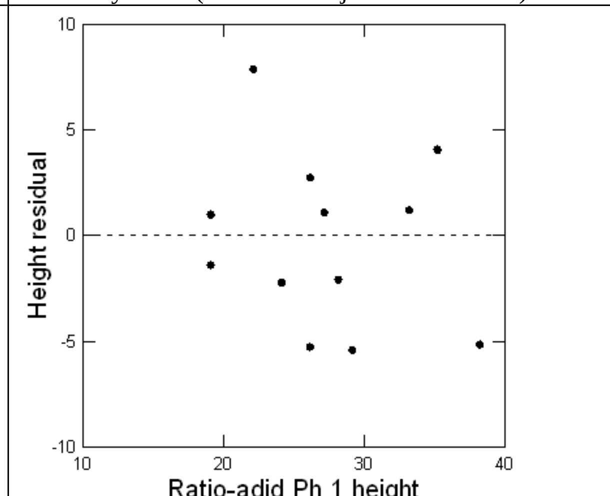

Fig F-14b: Height residuals vs adjusted Phase I inventory trees /ha (i.e. R × unadjusted Ph I trees /ha).

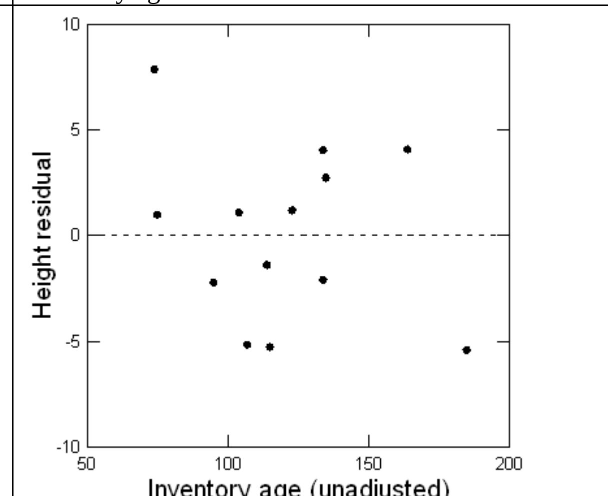

Fig F-14c: Trees /ha residuals vs unadjusted Phase I inventory age.

Fir leading stratum VRISTART *(Note: RESIDUAL = Phase II value – ratio-adjusted Phase I value)*

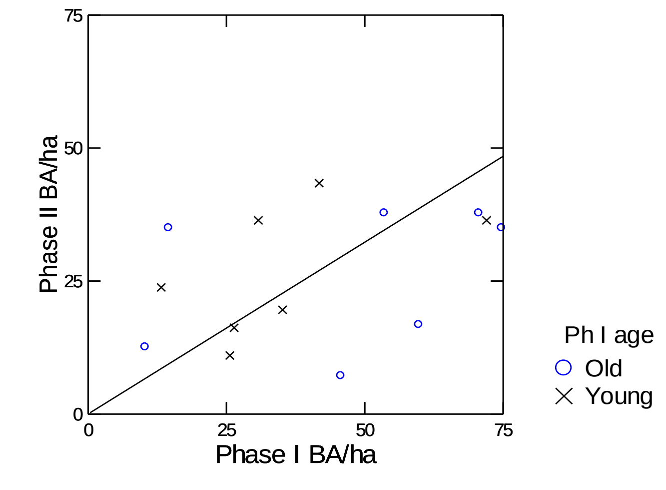

Fig F-15a: Phase II vs. Phase I ba/ha. The black line represents the ratio of means.

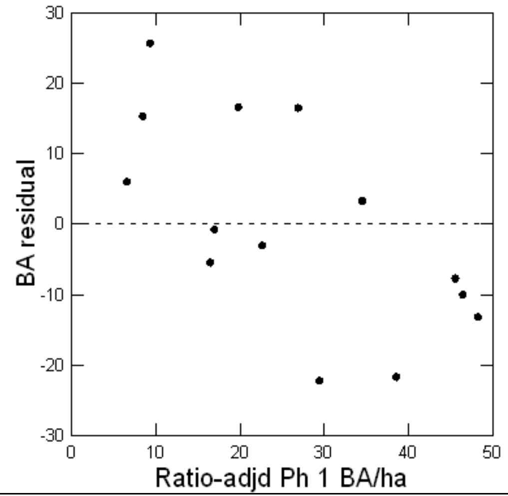

Fig F-15b: Ba/ha residuals vs adjusted Phase I inventory ba/ha (i.e. R × unadjusted Ph I ba/ha).

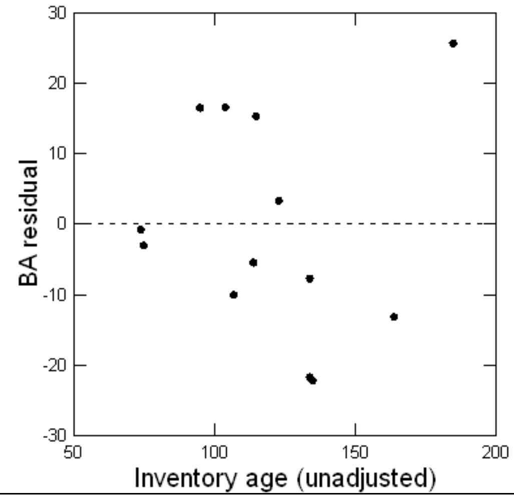

Fig F-15c: Ba/ha residuals vs unadjusted Phase I inventory age.

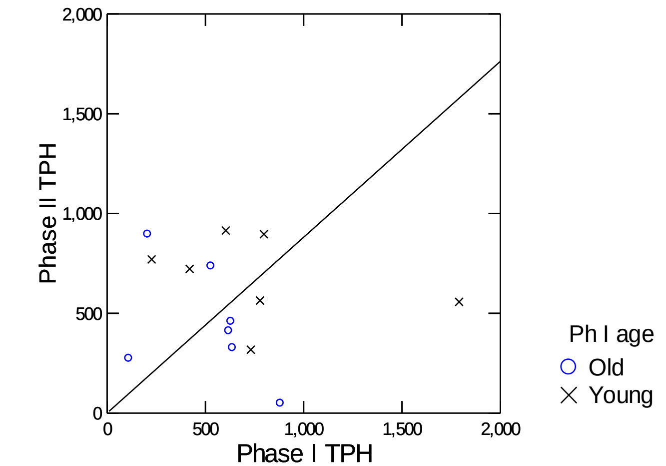

Fig F-16a: Phase II vs. Phase I trees/ha. The black line represents the ratio of means.

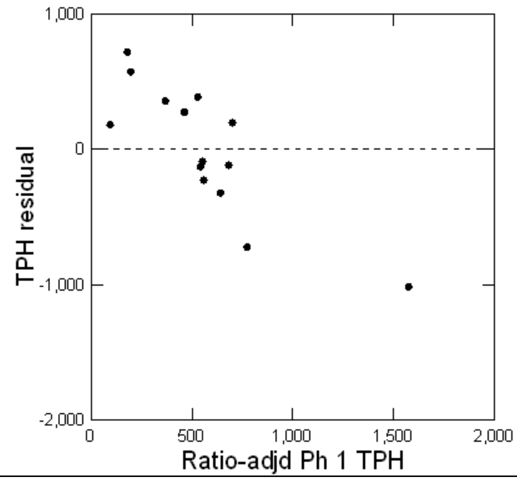

Fig F-16b: Trees/ha residuals vs adjusted Phase I inventory trees /ha (i.e. R × unadjusted Ph I trees /ha).

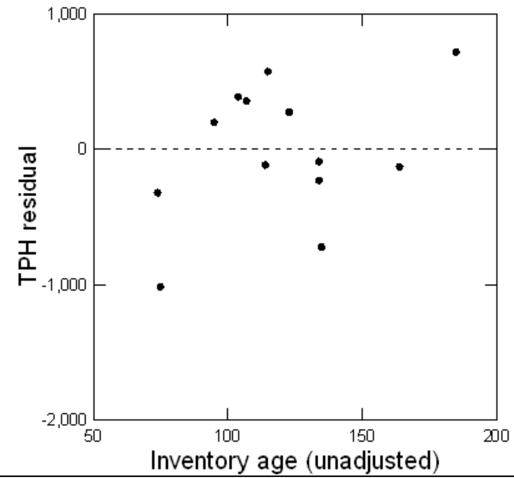

Fig F-16c: Trees /ha residuals vs unadjusted Phase I inventory age.

Fir leading stratum VRISTART (Note: RESIDUAL = Phase II value – ratio-adjusted Phase I value)

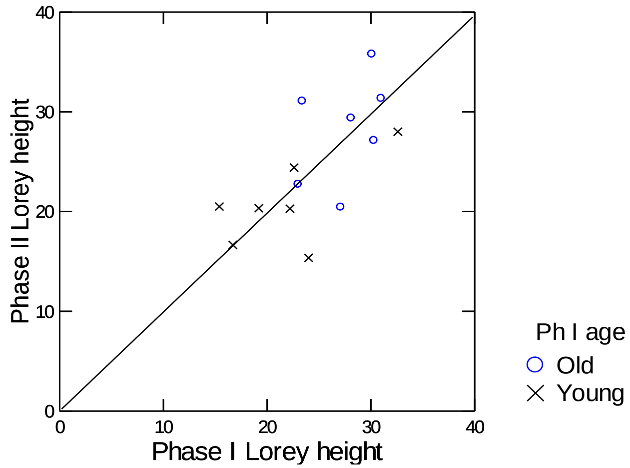

Fig F-17a: Phase II vs. Phase I Lorey height. The black line represents the ratio of means.

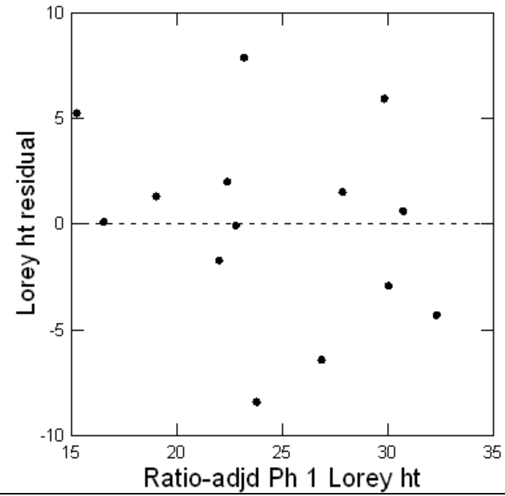

Fig F-17b: Lorey height residuals vs adjusted Phase I inventory Lorey height (i.e. R × unadjusted Ph I Lorey height).

Fig F-17c: Lorey height residuals vs unadjusted Phase I inventory age.

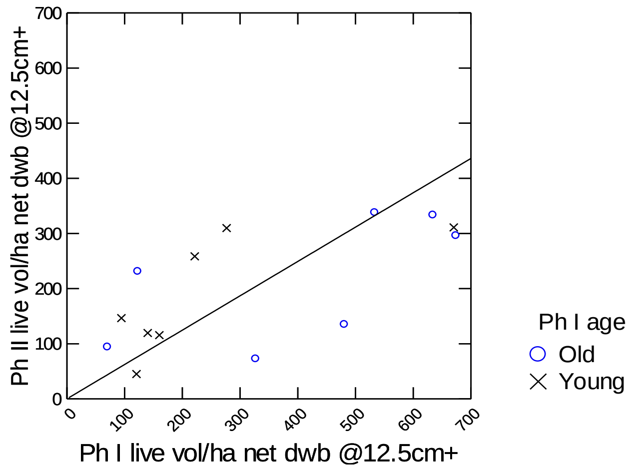

Fig F-18a: Phase II vs. Phase I vol/ha. The black line represents the ratio of means.

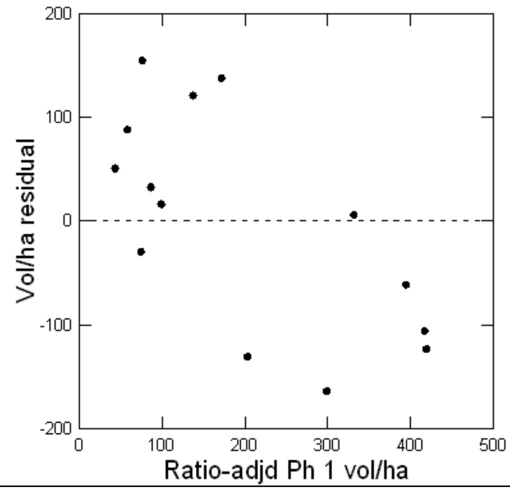

Fig F-18b: Vol/ha residuals vs adjusted Phase I inventory vol/ha (i.e. R × unadjusted Ph I vol/ha).

Fig F-18c: Vol/ha residuals vs unadjusted Phase I inventory age.

Other species leading stratum *(Note: RESIDUAL = Phase II value – ratio-adjusted Phase I value)*

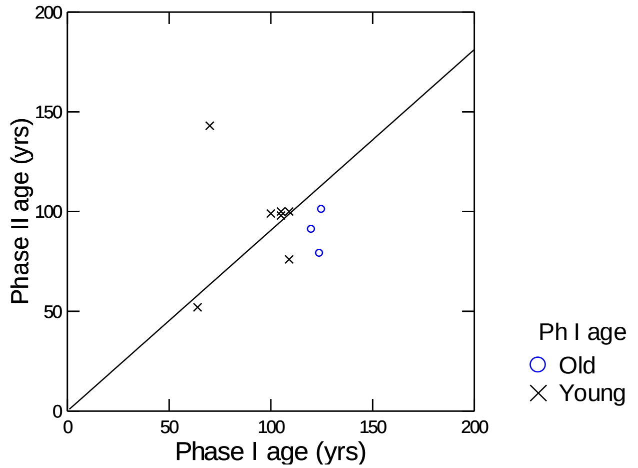

Fig F-19a: Phase II vs. Phase I age. The black line represents the ratio of means.

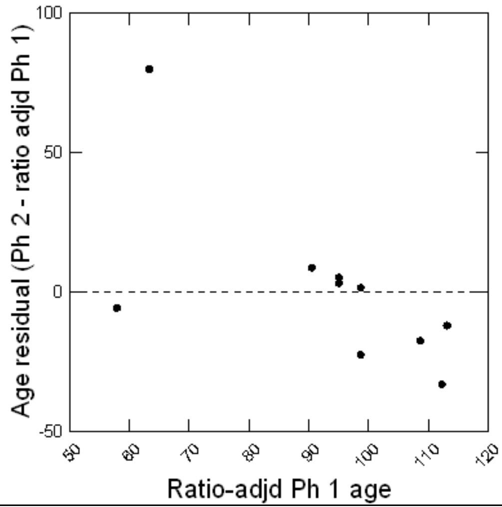

Fig F-19b: Age residuals vs adjusted Phase I inventory age (i.e. R × unadjusted Ph I age).

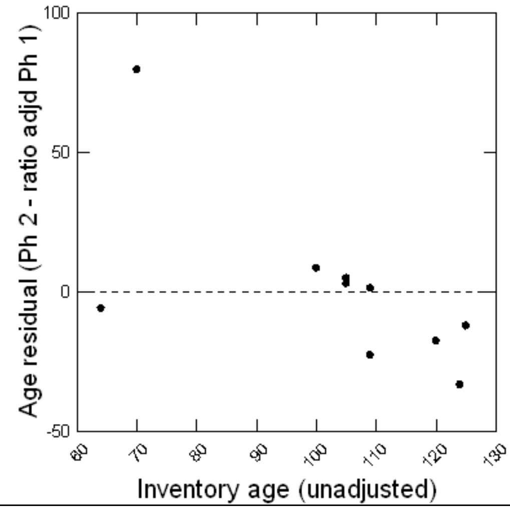

Fig F-19c: Age residuals vs unadjusted Phase I inventory age.

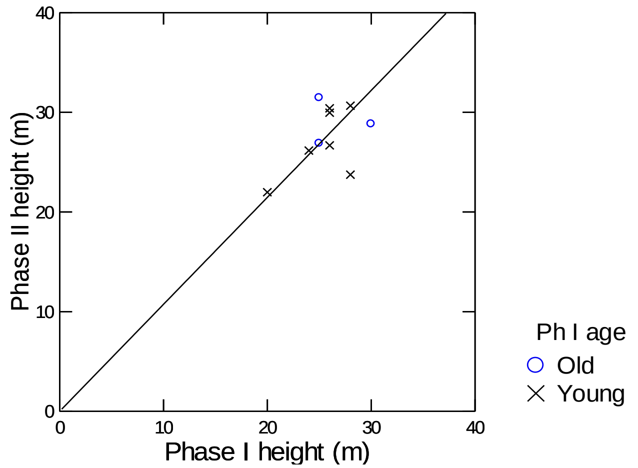

Fig F-20a: Phase II vs. Phase I height. The black line represents the ratio of means.

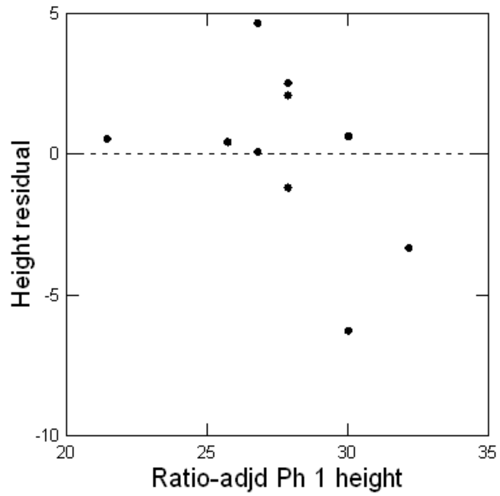

Fig F-20b: Height residuals vs adjusted Phase I inventory height (i.e. R × unadjusted Ph I height).

Fig F-20c: Height residuals vs unadjusted Phase I inventory age.

Other species leading stratum VRISTART *(Note: RESIDUAL = Phase II value – ratio-adjusted Phase I value)*

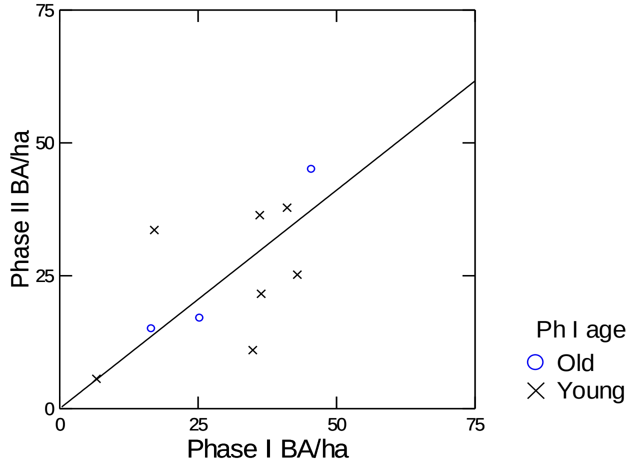

Fig F-21a: Phase II vs. Phase I ba/ha. The black line represents the ratio of means.

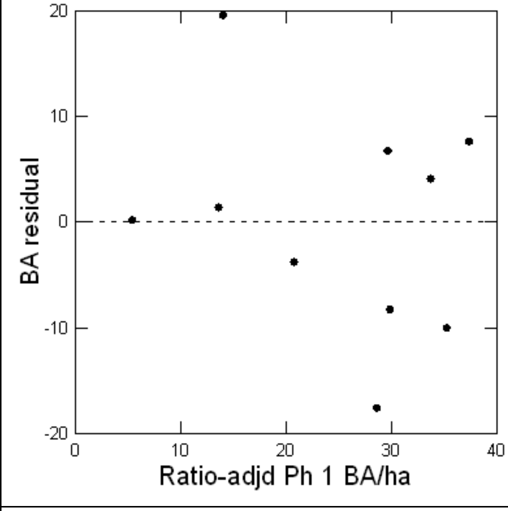

Fig F-21b: Ba/ha residuals vs adjusted Phase I inventory ba/ha (i.e. R × unadjusted Ph I ba/ha).

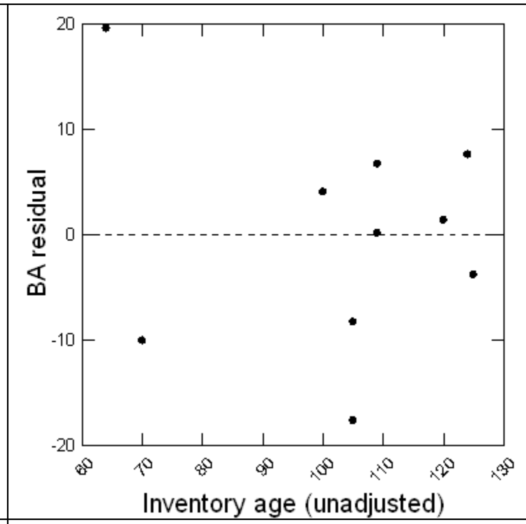

Fig F-21c: Ba/ha residuals vs unadjusted Phase I inventory age.

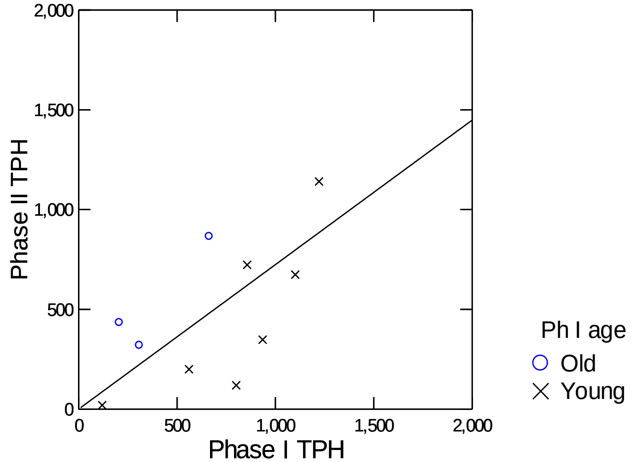

Fig F-22a: Phase II vs. Phase I trees/ha. The black line represents the ratio of means.

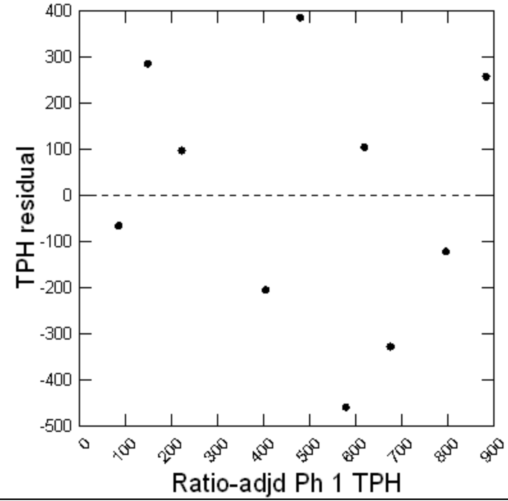

Fig F-22b: Trees/ha residuals vs adjusted Phase I inventory trees /ha (i.e. R × unadjusted Ph I trees /ha).

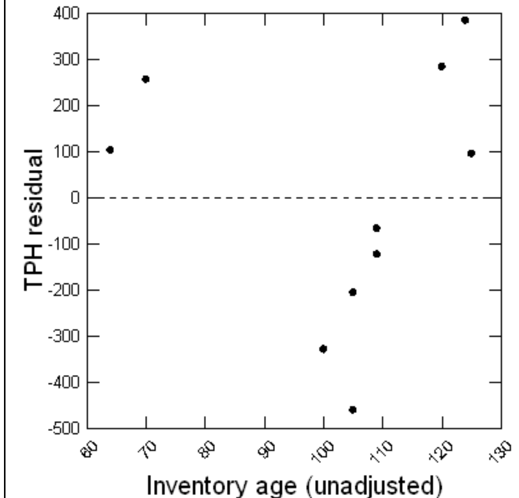

Fig F-22c: Trees /ha residuals vs unadjusted Phase I inventory age.

Other species leading stratum VRISTART *(Note: RESIDUAL = Phase II value – ratio-adjusted Phase I value)*

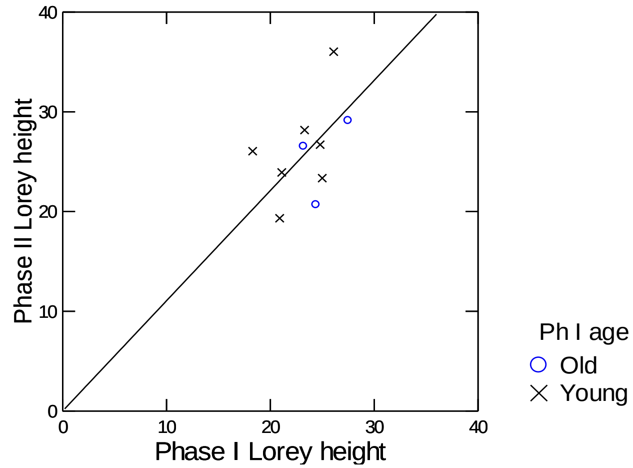

Fig F-23a: Phase II vs. Phase I Lorey height. The black line represents the ratio of means.

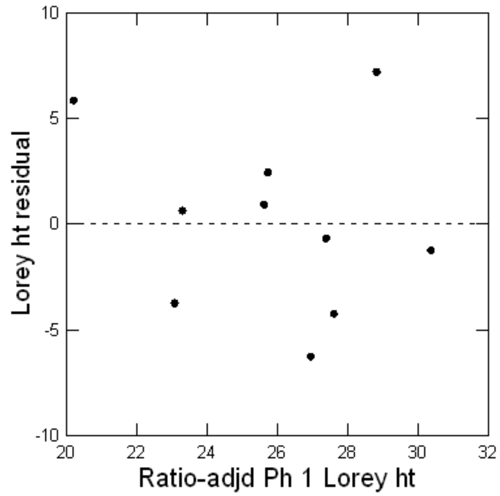

Fig F-23b: Lorey height residuals vs adjusted Phase I inventory Lorey height (i.e. R × unadjusted Ph I Lorey height).

Fig F-23c: Lorey height residuals vs unadjusted Phase I inventory age.

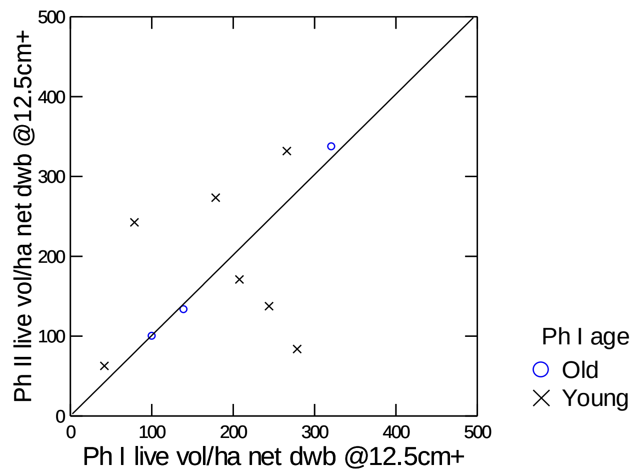

Fig F-24a: Phase II vs. Phase I vol/ha. The black line represents the ratio of means.

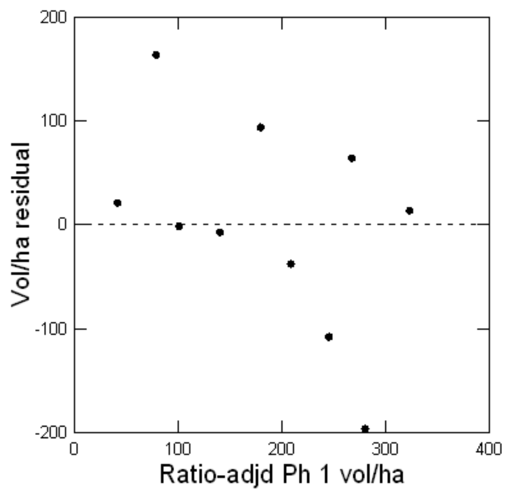

Fig F-24b: Vol/ha residuals vs adjusted Phase I inventory vol/ha (i.e. R × unadjusted Ph I vol/ha).

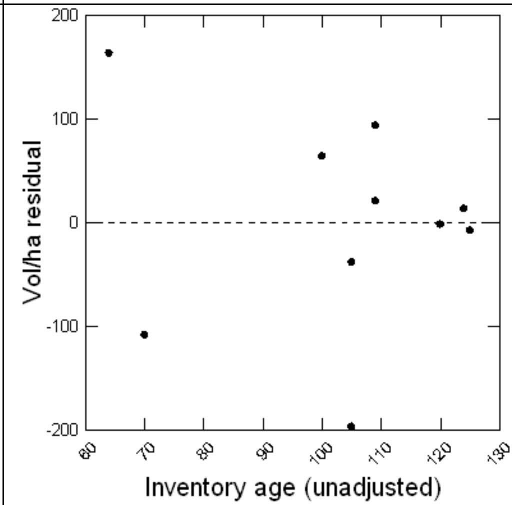

Fig F-24c: Vol/ha residuals vs unadjusted Phase I inventory age.

11. APPENDIX G: GRAPHS OF FIPSTART RELATIONSHIPS

Spruce leading: **FIPSTART relationships** (Note: “*RESIDUAL” = Phase II value – ratio-adjusted Phase I value)*

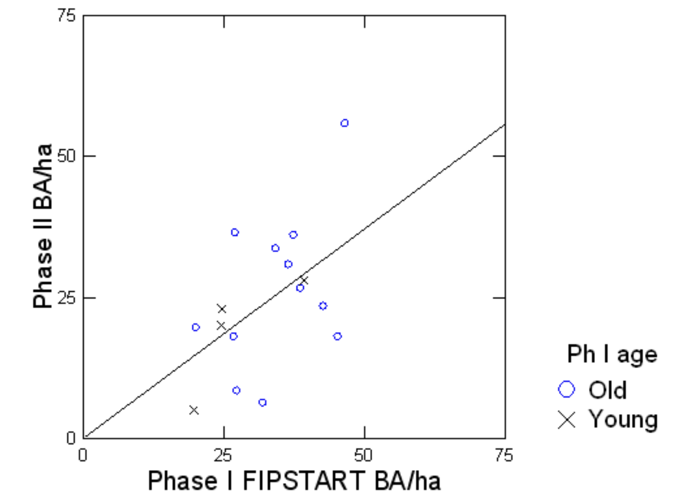

Fig G-1a: Phase II vs. Phase I ba/ha. The black line represents the ratio of means (R).

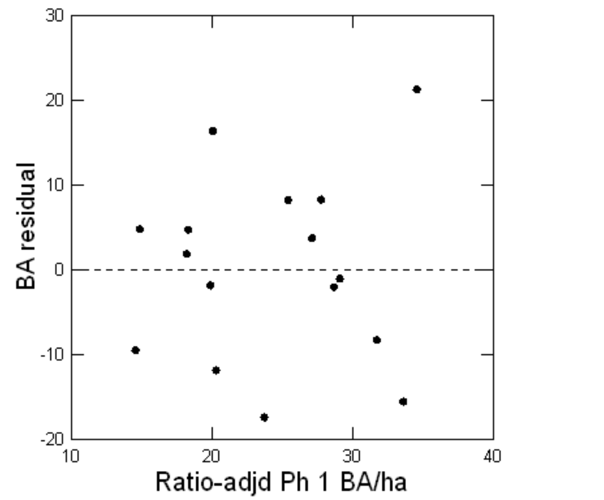

Fig G-1b: Ba/ha residuals vs adjusted Phase I inventory ba/ha (i.e. R × unadjusted Ph I ba/ha).

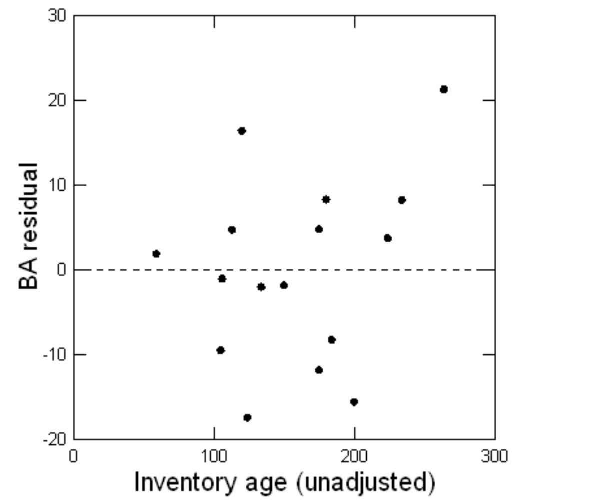

Fig G-1c: Ba/ha residuals vs unadjusted Phase I inventory age.

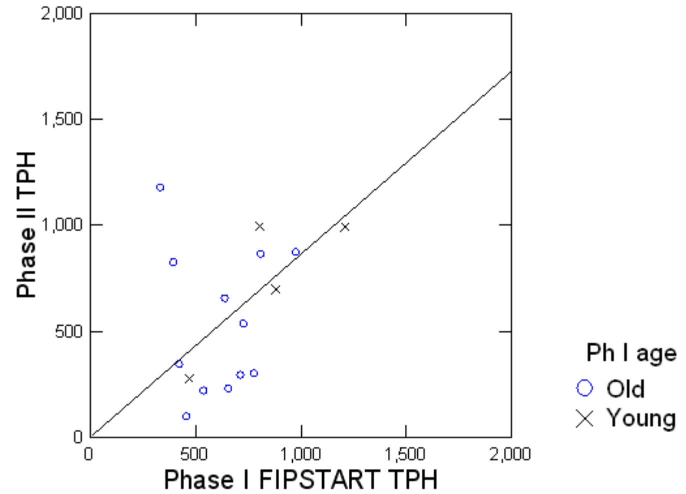

Fig G-2a: Phase II vs. Phase I trees/ha. The black line represents the ratio of means.

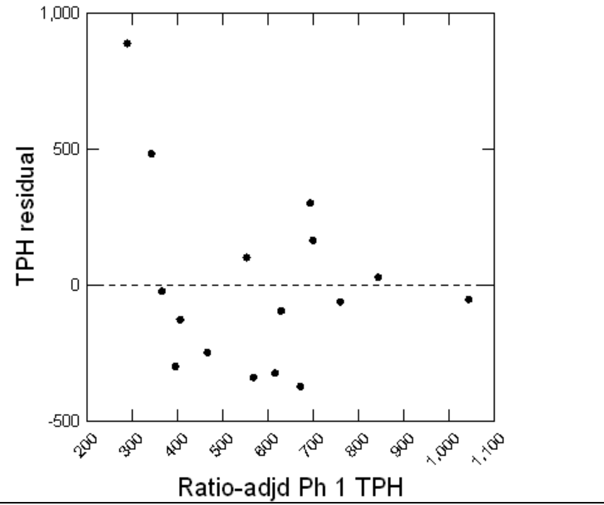

Fig G-2b: Trees/ha residuals vs adjusted Phase I inventory trees /ha (i.e. R × unadjusted Ph I trees /ha).

Fig G-2c: Trees /ha residuals vs unadjusted Phase I inventory age.

Spruce leading: **FIPSTART relationships** (Note: "*RESIDUAL" = Phase II value – ratio-adjusted Phase I value)*

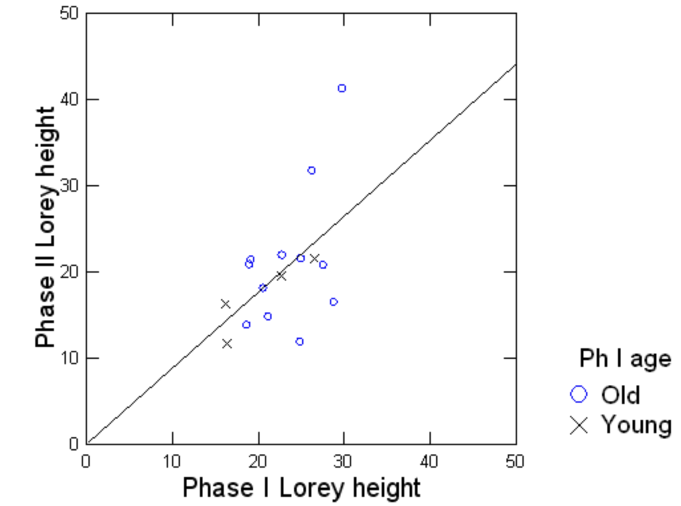

Fig G-3a: Phase II vs. Phase I Lorey height. The black line represents the ratio of means.

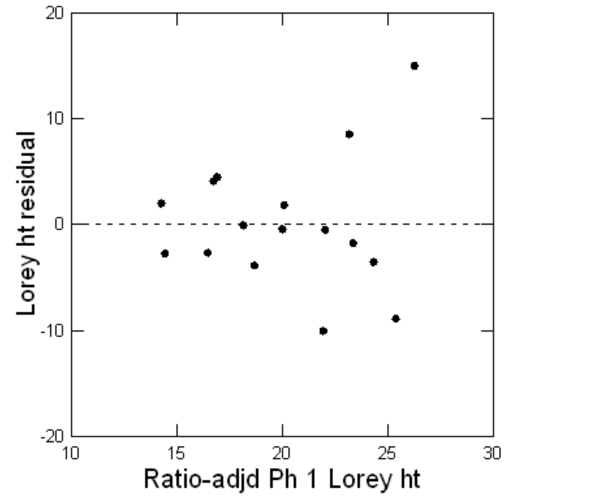

Fig G-3b: Lorey height residuals vs adjusted Phase I inventory Lorey height (i.e. R × unadjusted Ph I Lorey height).

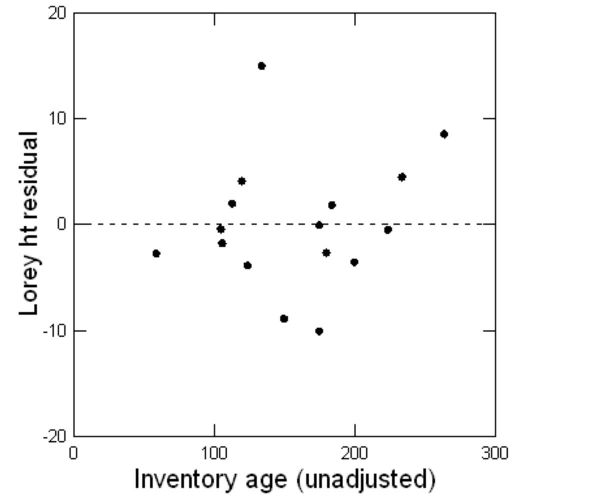

Fig G-3c: Lorey height residuals vs unadjusted Phase I inventory age.

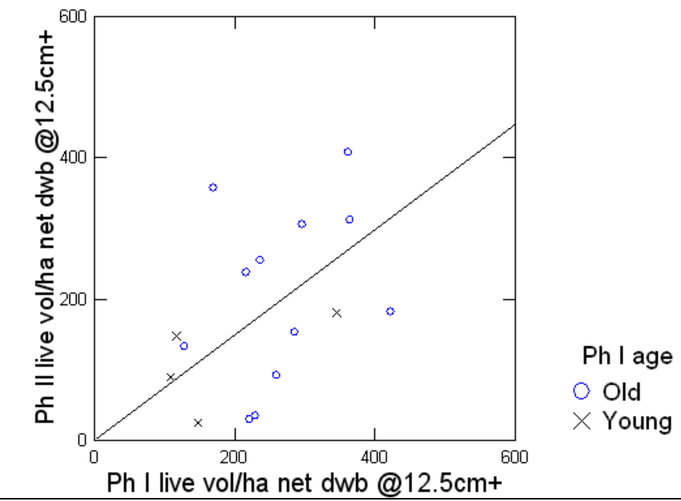

Fig G-4a: Phase II vs. Phase I vol/ha. The black line represents the ratio of means.

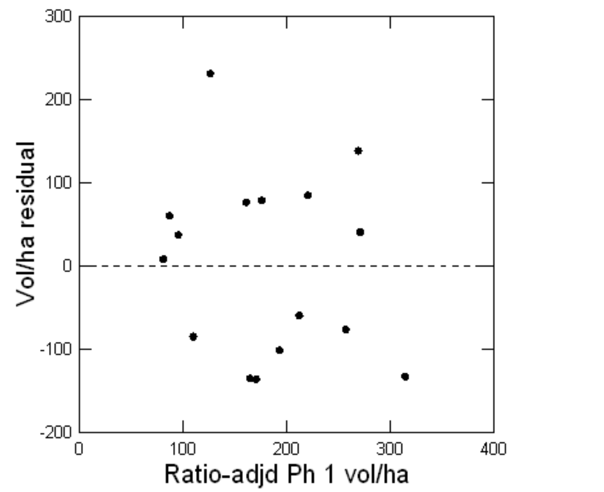

Fig G-4b: Vol/ha residuals vs adjusted Phase I inventory vol/ha (i.e. R × unadjusted Ph I vol/ha).

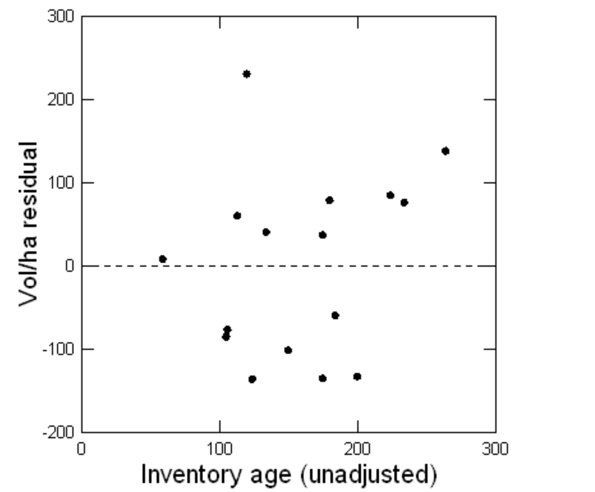

Fig G-4c: Vol/ha residuals vs unadjusted Phase I inventory age.

Balsam leading: **FIPSTART relationships** (Note: "*RESIDUAL" = Phase II value – ratio-adjusted Phase I value)*

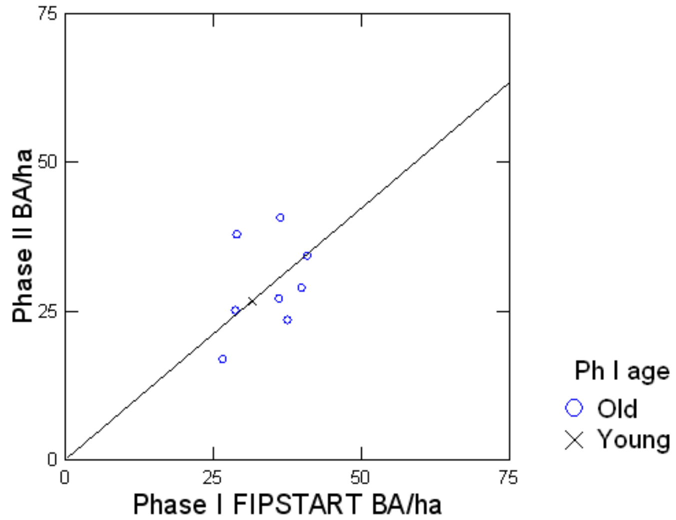

Fig G-5a: Phase II vs. Phase I ba/ha. The black line represents the ratio of means (R).

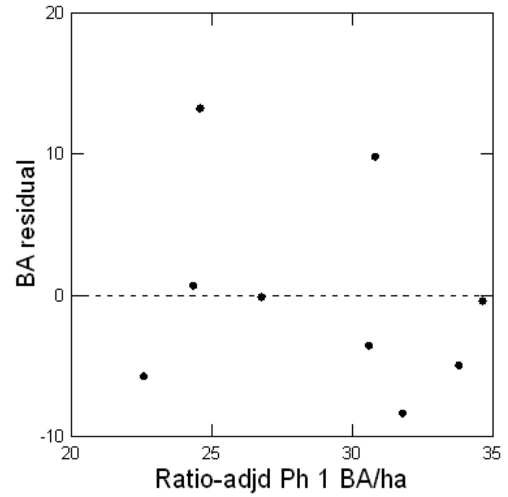

Fig G-5b: Ba/ha residuals vs adjusted Phase I inventory ba/ha (i.e. R × unadjusted Ph I ba/ha).

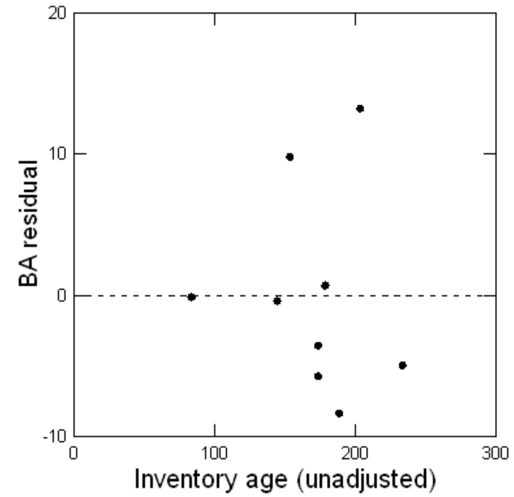

Fig G-5c: Ba/ha residuals vs unadjusted Phase I inventory age.

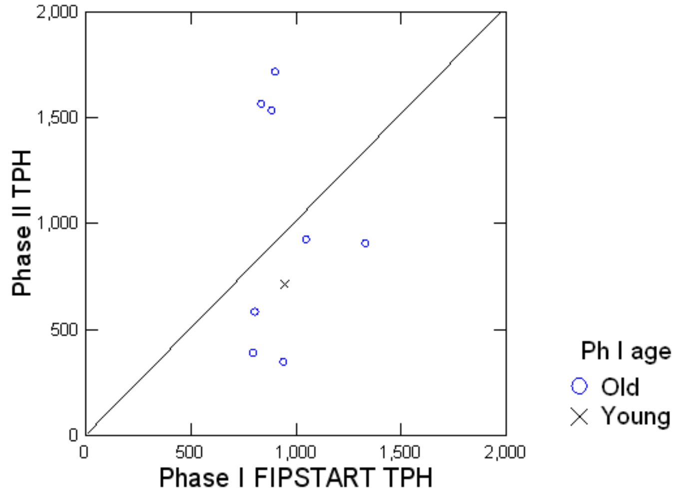

Fig G-6a: Phase II vs. Phase I trees/ha. The black line represents the ratio of means.

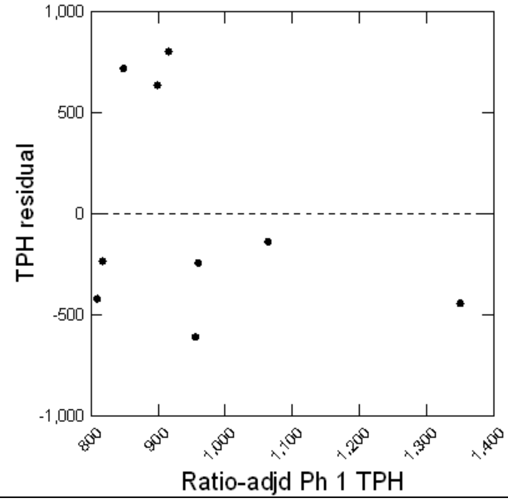

Fig G-6b: Trees/ha residuals vs adjusted Phase I inventory trees /ha (i.e. R × unadjusted Ph I trees /ha).

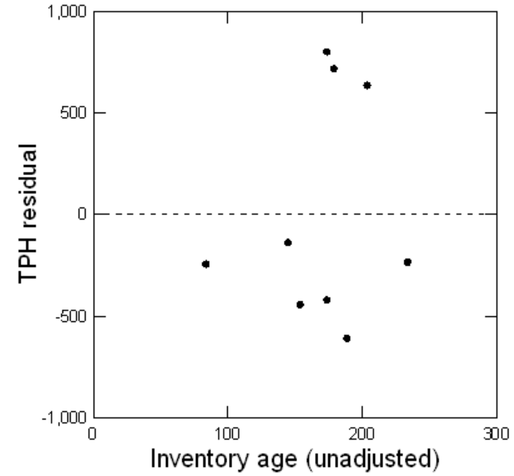

Fig G-6c: Trees /ha residuals vs unadjusted Phase I inventory age.

Balsam leading: **FIPSTART relationships** (Note: "*RESIDUAL*" = *Phase II value – ratio-adjusted Phase I value)*

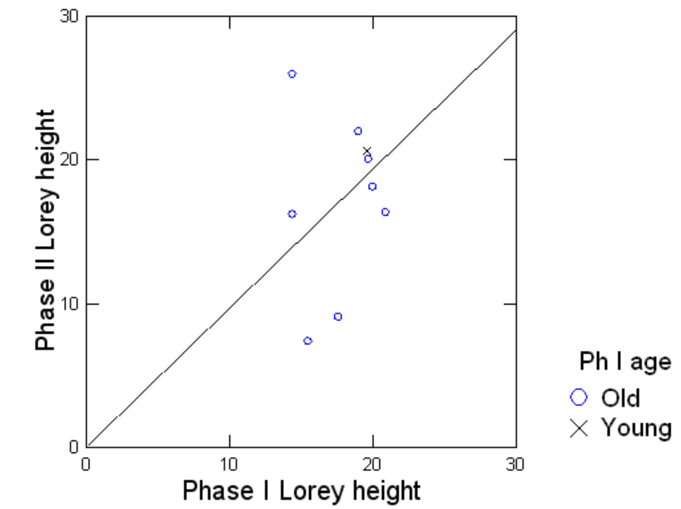

Fig G-7a: Phase II vs. Phase I Lorey height. The black line represents the ratio of means.

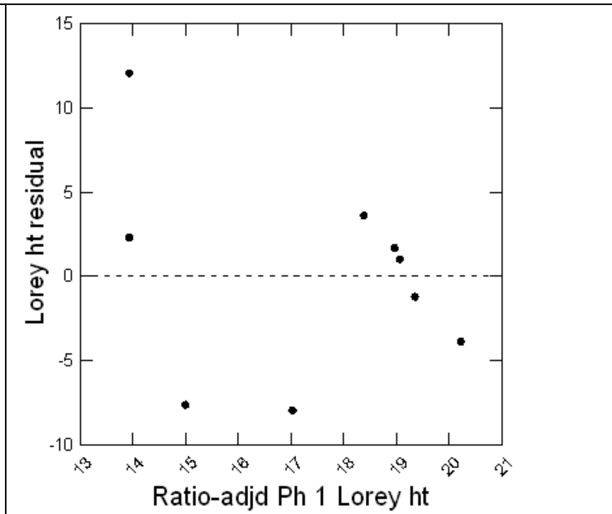

Fig G-7b: Lorey height residuals vs adjusted Phase I inventory Lorey height (i.e. R × unadjusted Ph I Lorey height).

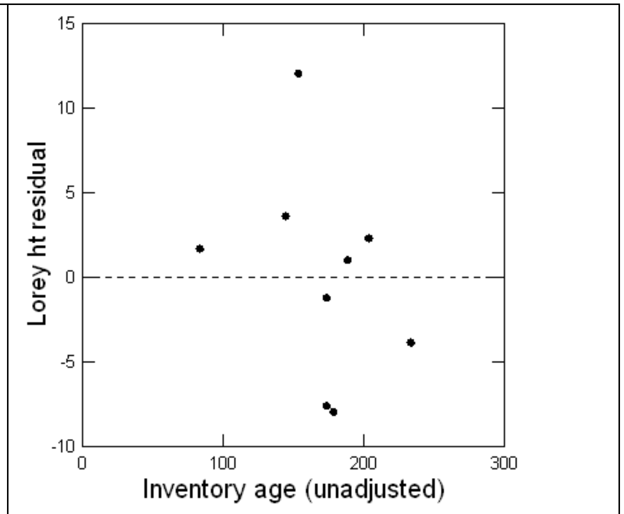

Fig G-7c: Lorey height residuals vs unadjusted Phase I inventory age.

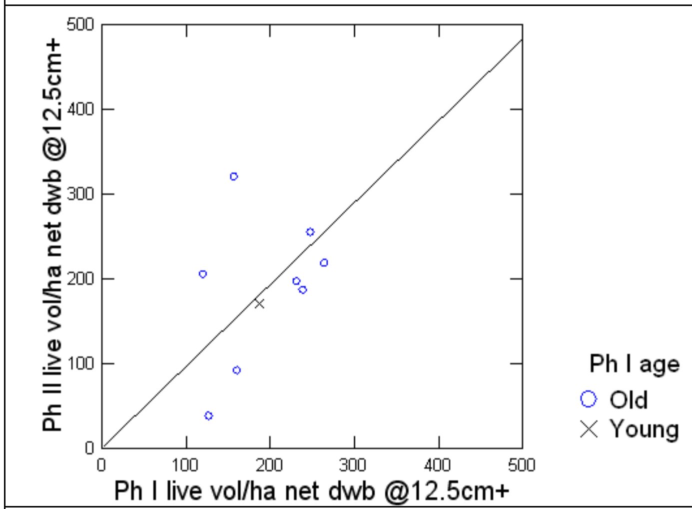

Fig G-8a: Phase II vs. Phase I vol/ha. The black line represents the ratio of means.

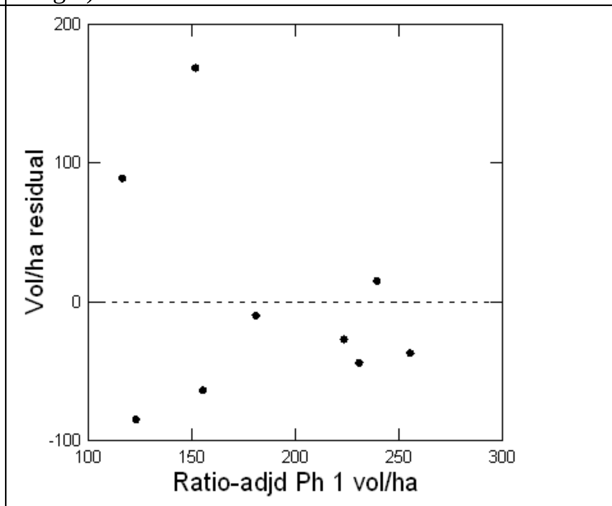

Fig G-8b: Vol/ha residuals vs adjusted Phase I inventory vol/ha (i.e. R × unadjusted Ph I vol/ha).

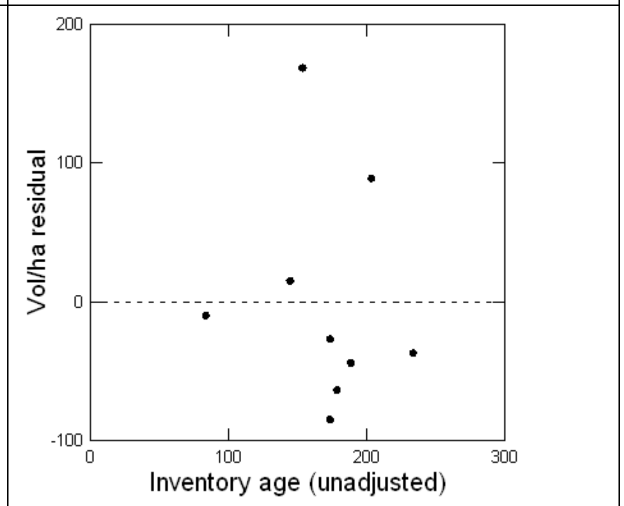

Fig G-8c: Vol/ha residuals vs unadjusted Phase I inventory age.

***Fir leading:* FIPSTART relationships** (Note: "*RESIDUAL*" *= Phase II value – ratio-adjusted Phase I value)*

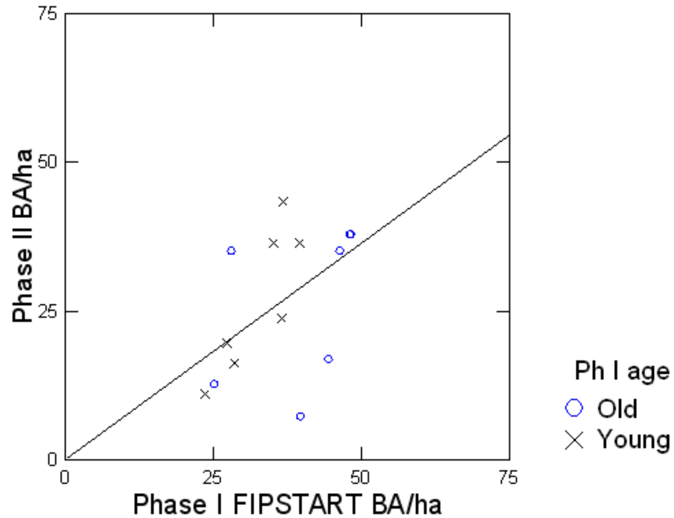

Fig G-9a: Phase II vs. Phase I ba/ha. The black line represents the ratio of means (R).

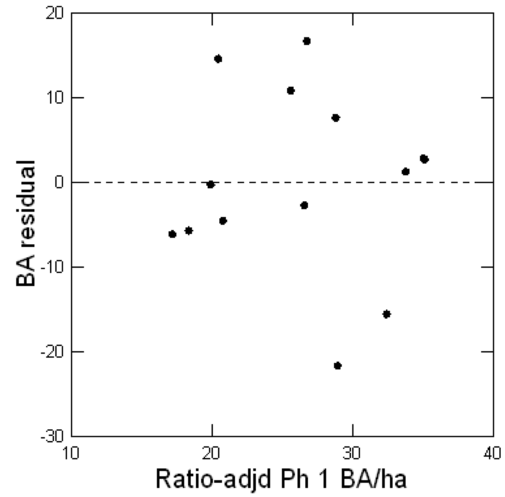

Fig G-9b: Ba/ha residuals vs adjusted Phase I inventory ba/ha (i.e. R × unadjusted Ph I ba/ha).

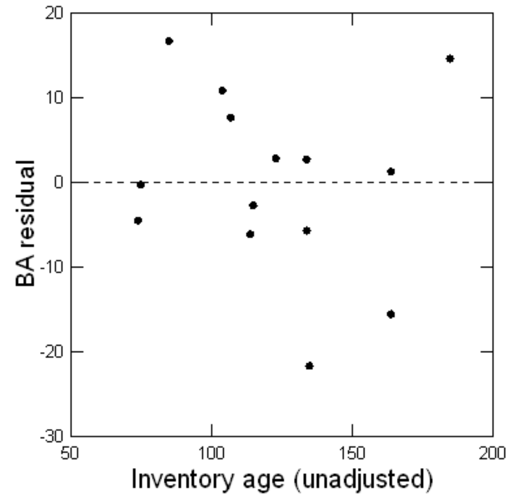

Fig G-9c: Ba/ha residuals vs unadjusted Phase I inventory age.

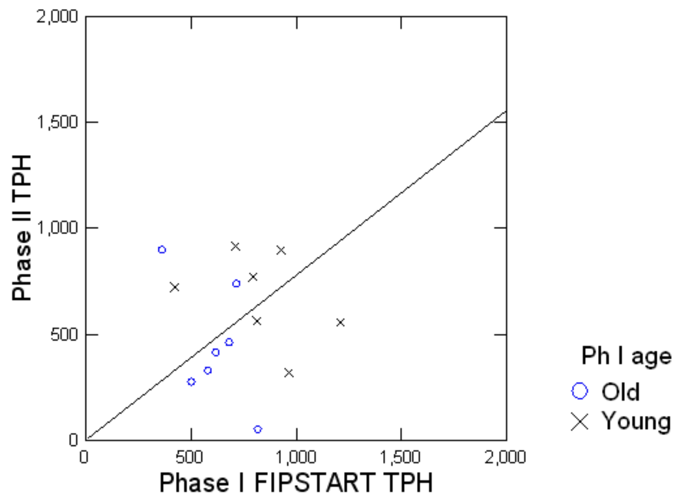

Fig G-10a: Phase II vs. Phase I trees/ha. The black line represents the ratio of means.

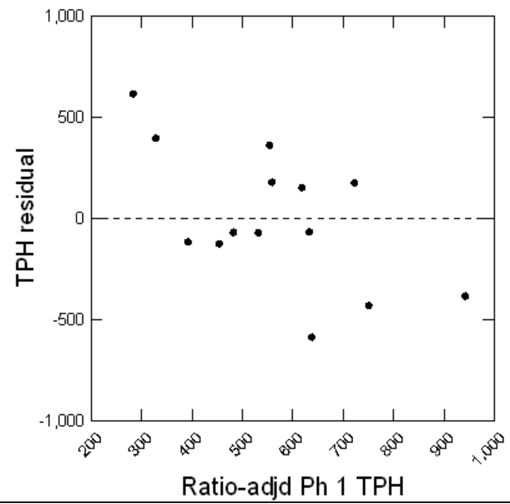

Fig G-10b: Trees/ha residuals vs adjusted Phase I inventory trees /ha (i.e. R × unadjusted Ph I trees /ha).

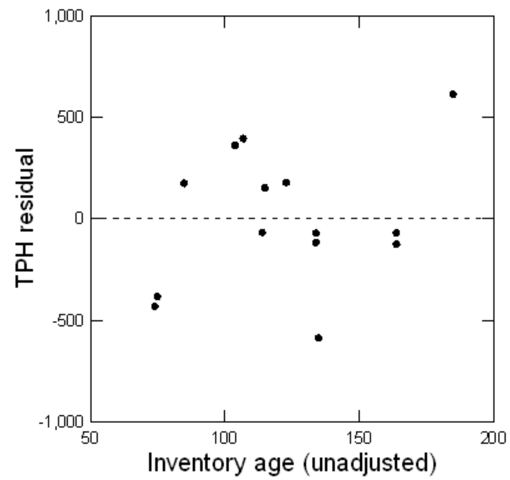

Fig G-10c: Trees /ha residuals vs unadjusted Phase I inventory age.

Fir leading: **FIPSTART relationships** (Note: "*RESIDUAL" = Phase II value – ratio-adjusted Phase I value)*

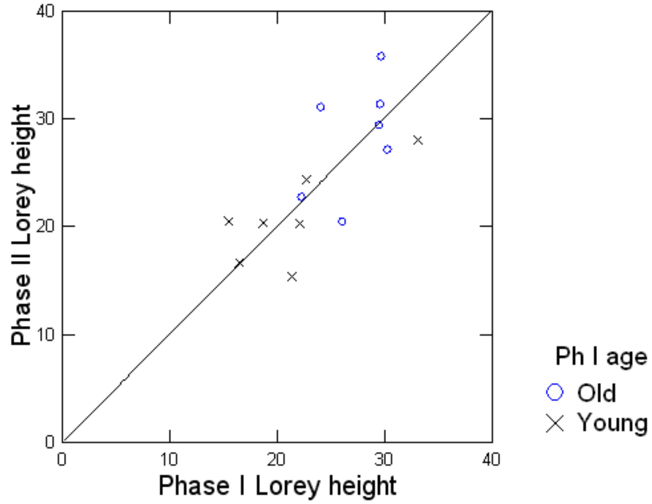

Fig G-11a: Phase II vs. Phase I Lorey height. The black line represents the ratio of means.

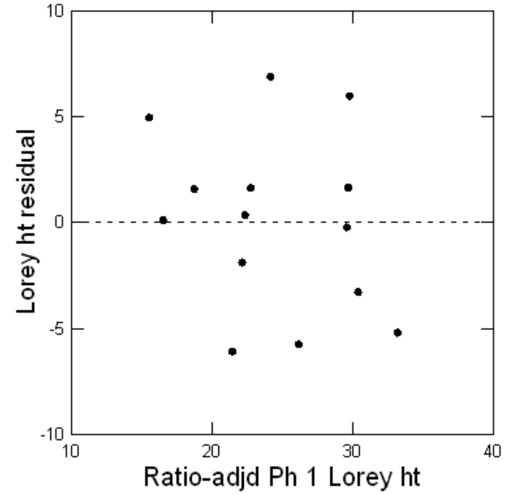

Fig G-11b: Lorey height residuals vs adjusted Phase I inventory Lorey height (i.e. R × unadjusted Ph I Lorey height).

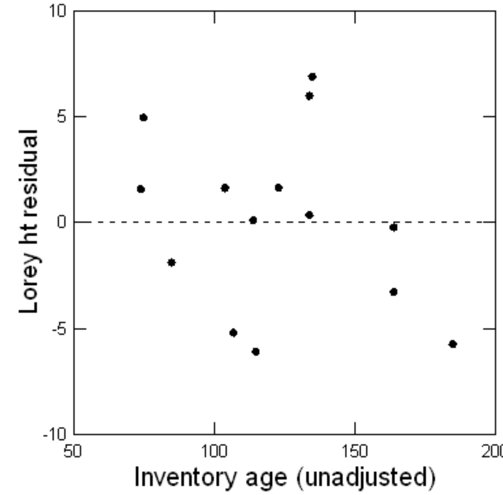

Fig G-11c: Lorey height residuals vs unadjusted Phase I inventory age.

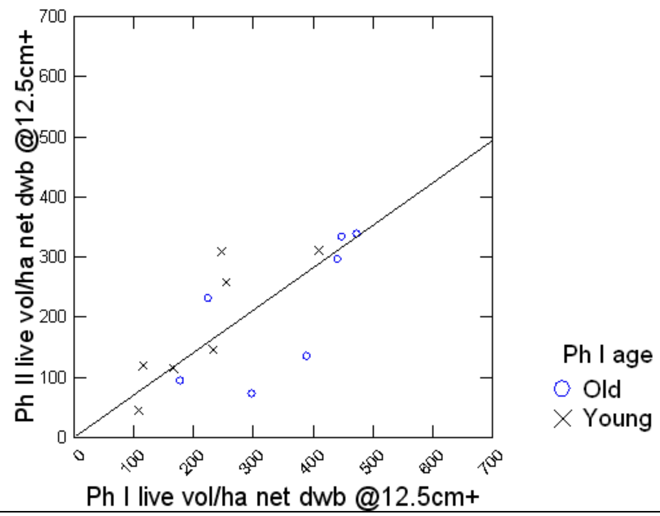

Fig G-12a: Phase II vs. Phase I vol/ha. The black line represents the ratio of means.

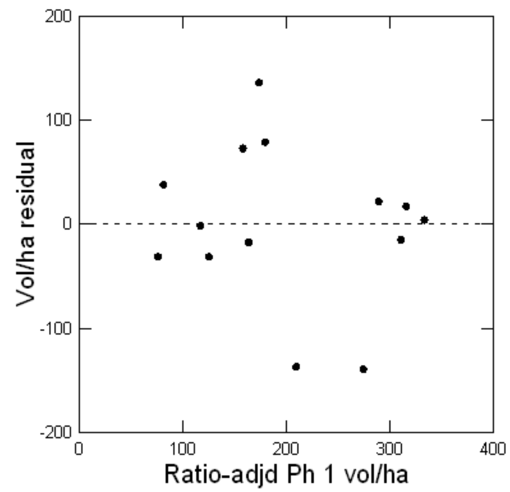

Fig G-12b: Vol/ha residuals vs adjusted Phase I inventory vol/ha (i.e. R × unadjusted Ph I vol/ha).

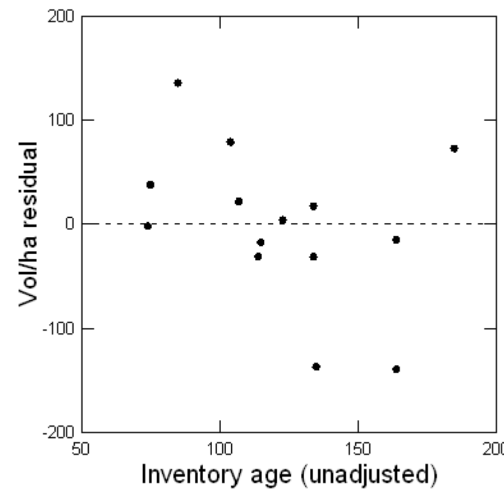

Fig G-12c: Vol/ha residuals vs unadjusted Phase I inventory age.

Other species leading: **FIPSTART relationships** (Note: "*RESIDUAL*" = *Phase II value – ratio-adjusted Phase I value)*

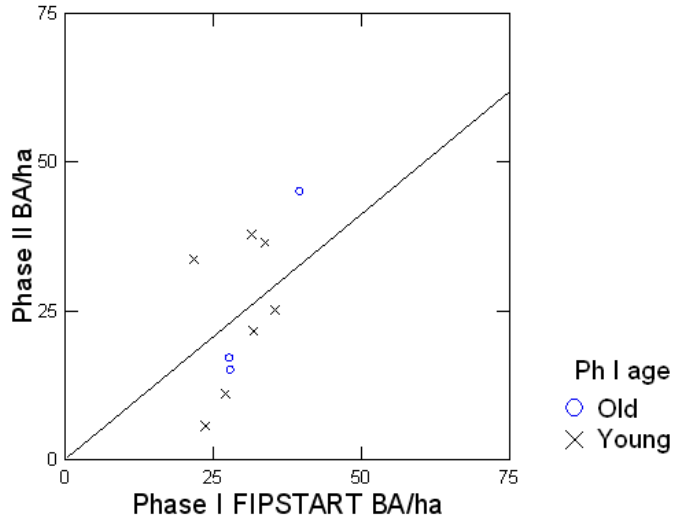

Fig G-13a: Phase II vs. Phase I ba/ha. The black line represents the ratio of means (R).

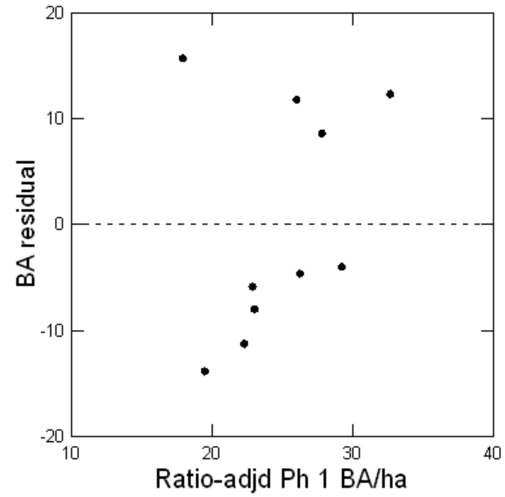

Fig G-13b: Ba/ha residuals vs adjusted Phase I inventory ba/ha (i.e. R × unadjusted Ph I ba/ha).

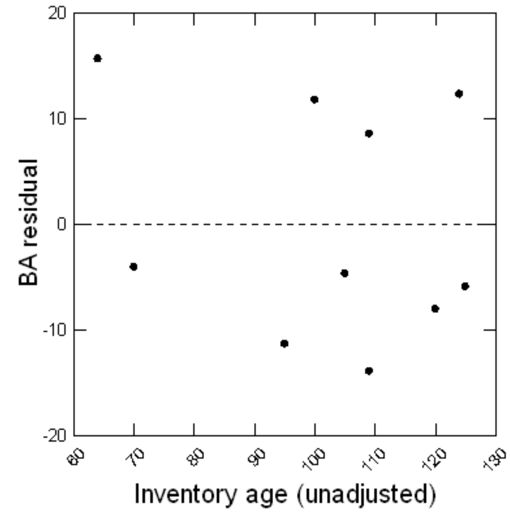

Fig G-13c: Ba/ha residuals vs unadjusted Phase I inventory age.

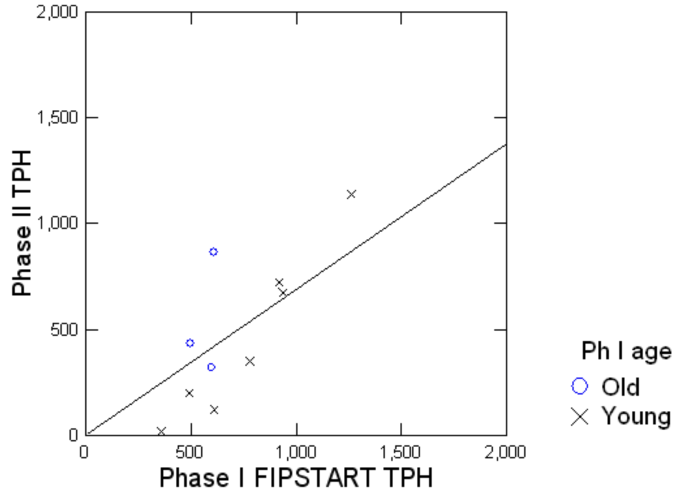

Fig G-14a: Phase II vs. Phase I trees/ha. The black line represents the ratio of means.

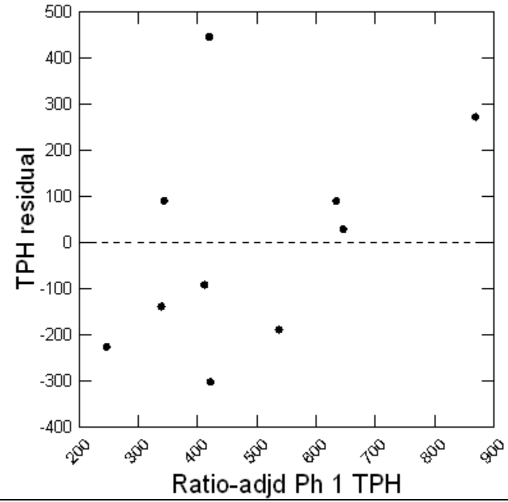

Fig G-14b: Trees/ha residuals vs adjusted Phase I inventory trees /ha (i.e. R × unadjusted Ph I trees /ha).

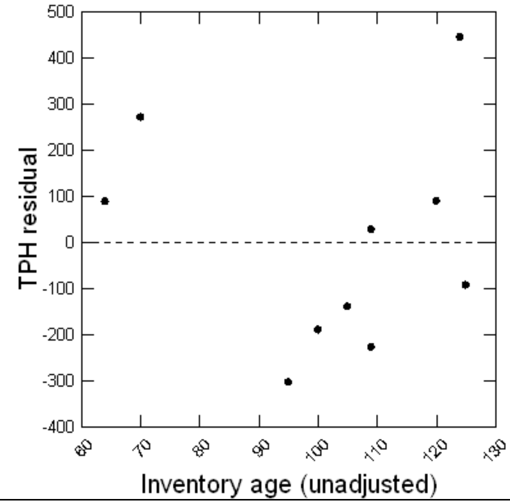

Fig G-14c: Trees /ha residuals vs unadjusted Phase I inventory age.

Other species leading: **FIPSTART relationships** (Note: "*RESIDUAL" = Phase II value – ratio-adjusted Phase I value)*

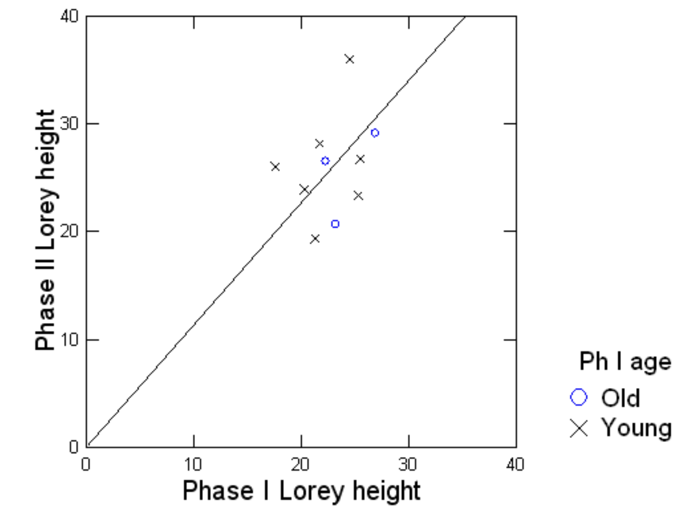

Fig G-15a: Phase II vs. Phase I Lorey height. The black line represents the ratio of means.

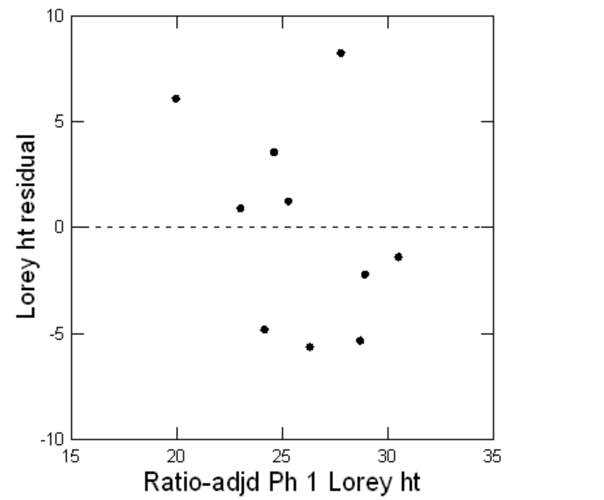

Fig G-15b: Lorey height residuals vs adjusted Phase I inventory Lorey height (i.e. R × unadjusted Ph I Lorey height).

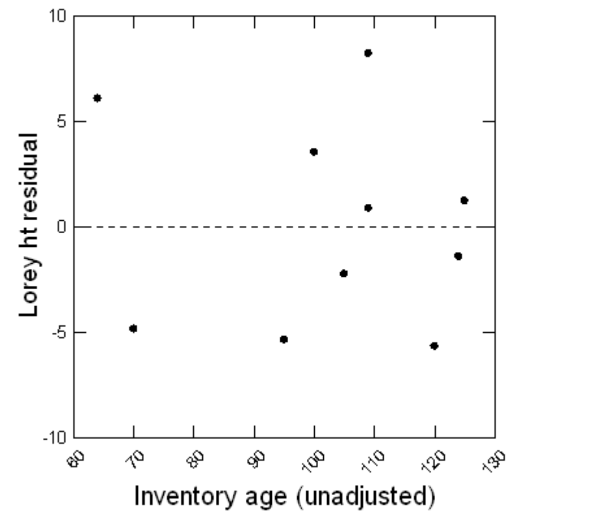

Fig G-15c: Lorey height residuals vs unadjusted Phase I inventory age.

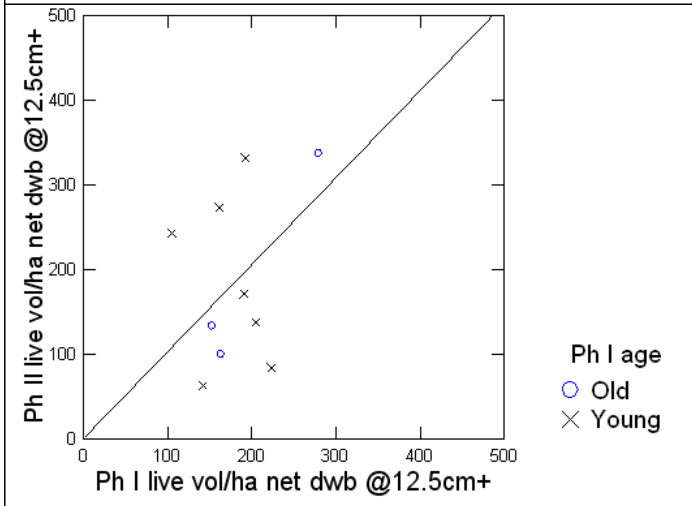

Fig G-16a: Phase II vs. Phase I vol/ha. The black line represents the ratio of means.

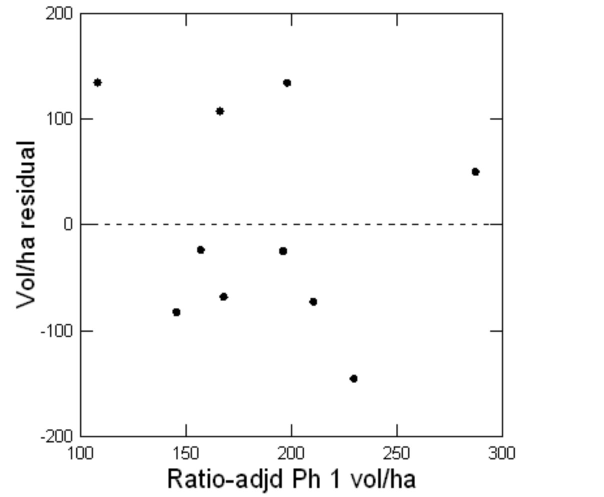

Fig G-16b: Vol/ha residuals vs adjusted Phase I inventory vol/ha (i.e. R × unadjusted Ph I vol/ha).

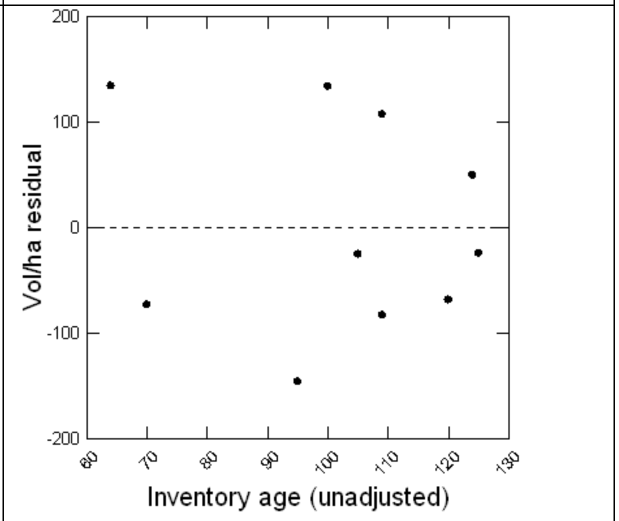

Fig G-16c: Vol/ha residuals vs unadjusted Phase I inventory age.

12. APPENDIX H: VDYP7 VRISTART VS. FIPSTART BA/HA RESIDUALS

(Phase II – Phase I BA values) as a function of VRISTART Ph I BA/ha

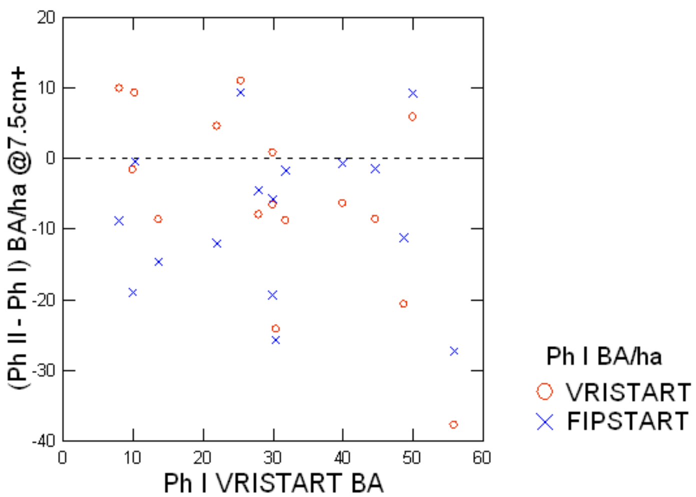

Fig H-1: “Spruce leading” stratum.

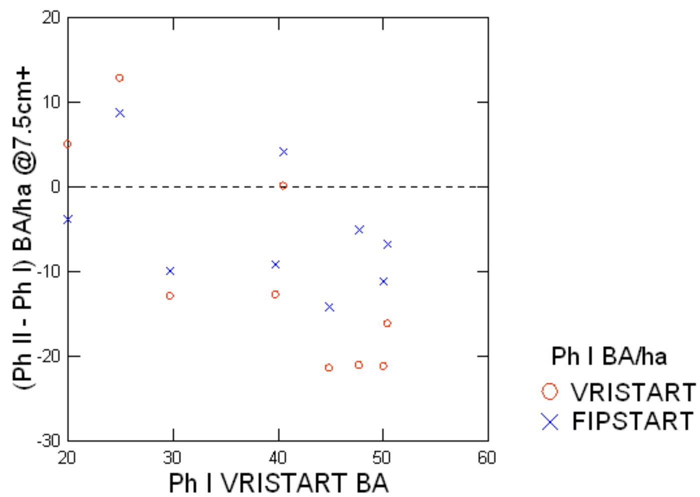

Fig H-2: “Balsam leading” stratum.

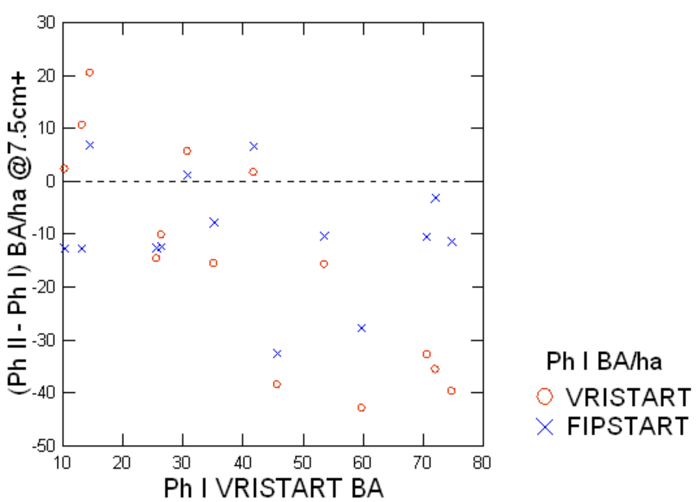

Fig H-3: “Fir leading” stratum.

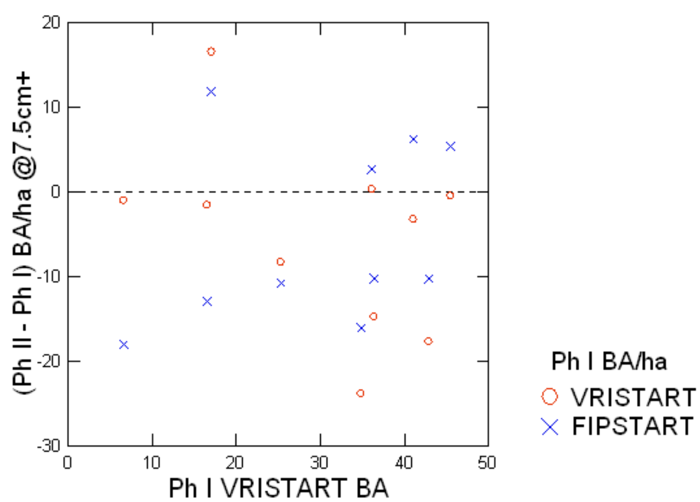

Fig H-4: “Other spp leading” stratum.

(Phase II – Phase I BA values) as a function of FIPSTART Ph I BA/ha

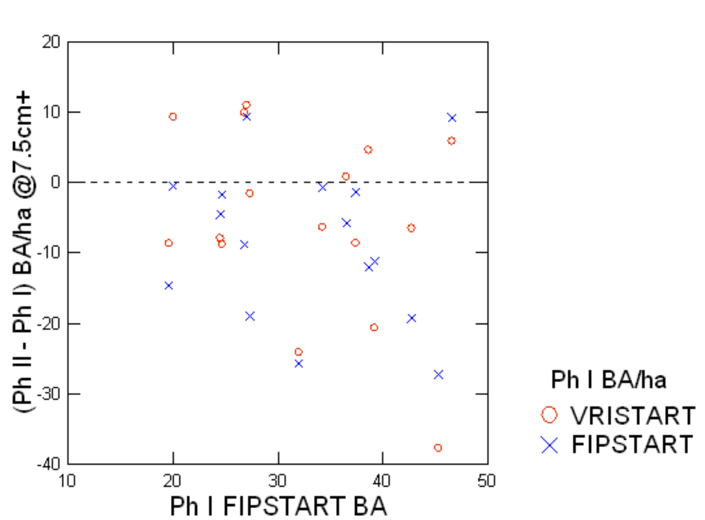

Fig H-5: "Spruce leading" stratum.

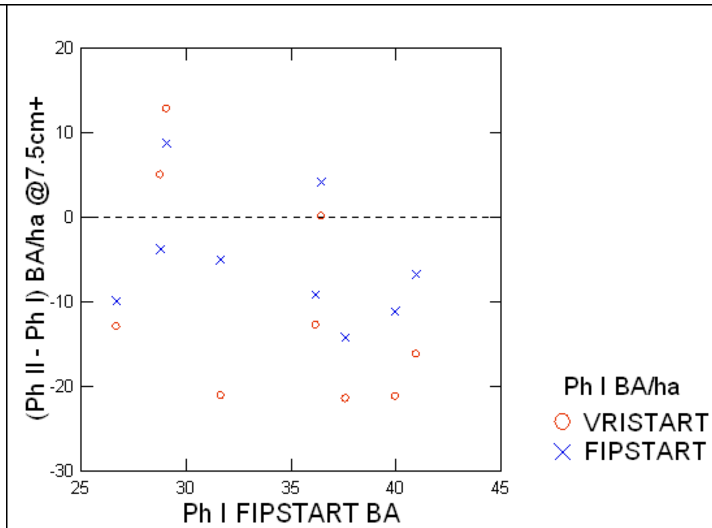

Fig H-6: "Balsam leading" stratum.

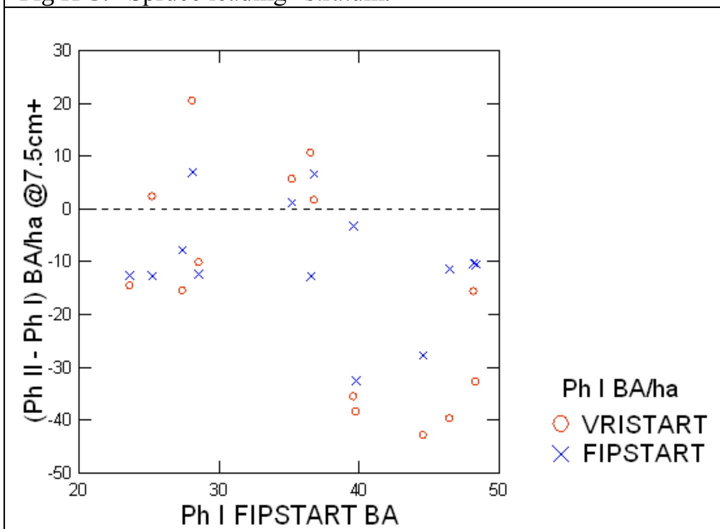

Fig H-7: "Fir leading" stratum.

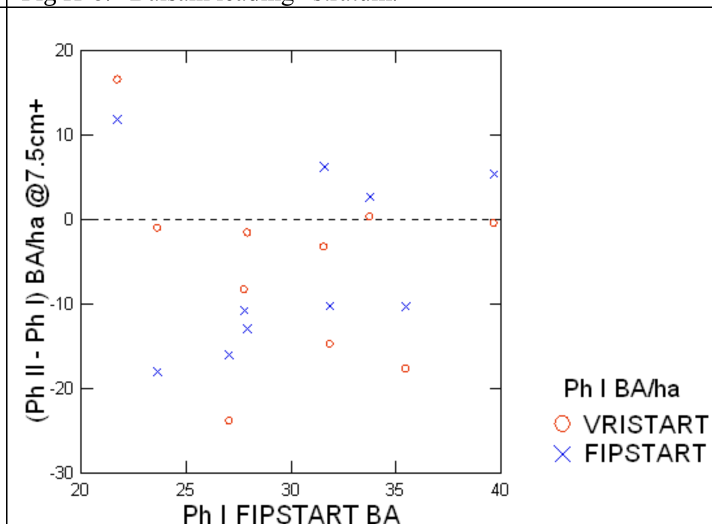

Fig H-8: "Other spp leading" stratum.

(Phase II – Phase I BA values) as a function of Phase I age

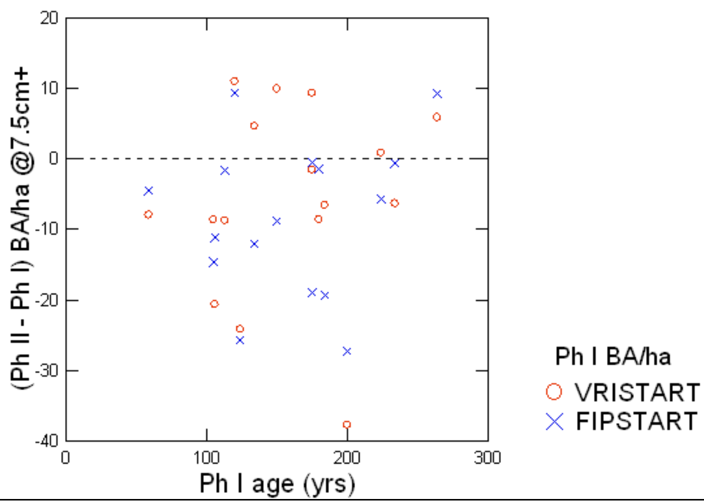

Fig H-9: “Spruce leading” stratum.

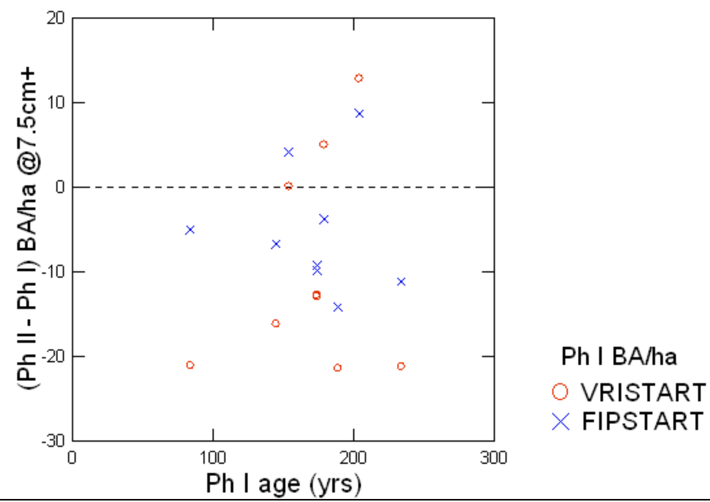

Fig H-10: “Balsam leading” stratum.

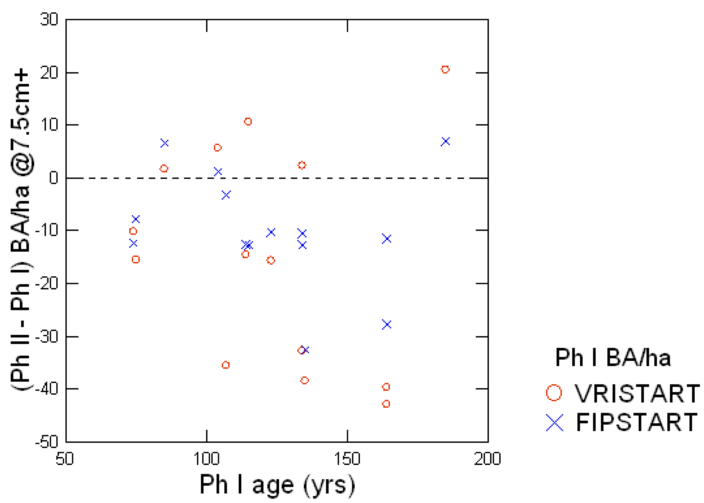

Fig H-11: “Fir leading” stratum.

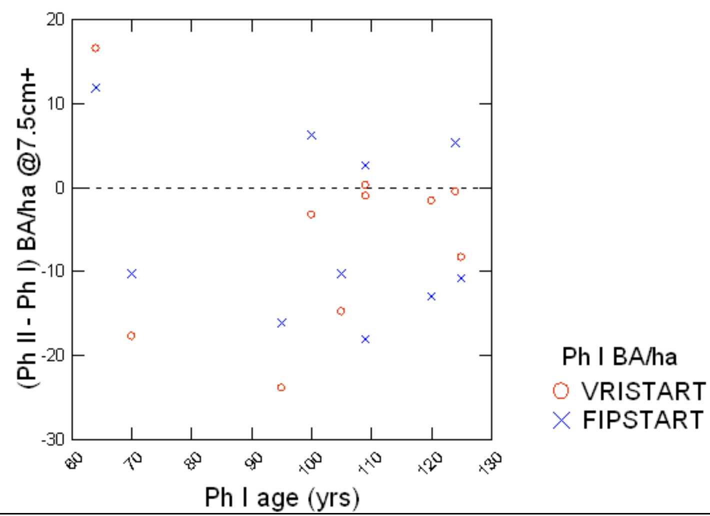

Fig H-12: “Other spp leading” stratum.

(Phase II – Phase I BA values) as a function of Phase I height

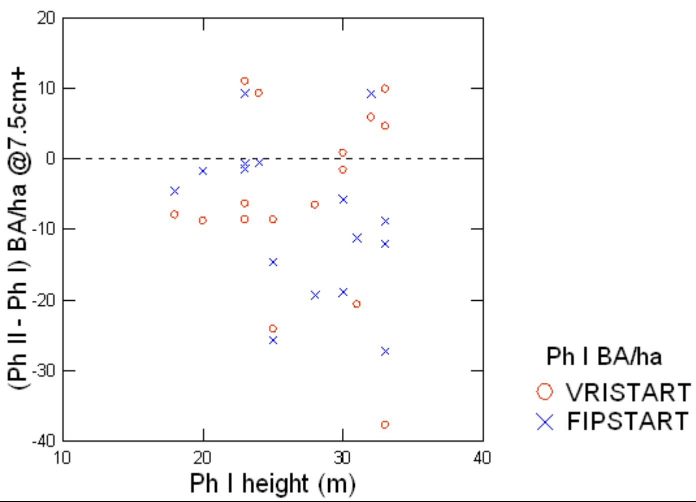

Fig H-13: “Spruce leading” stratum.

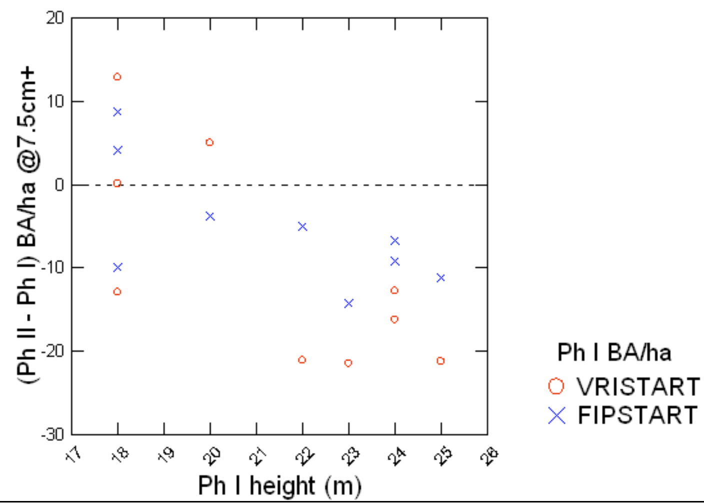

Fig H-14: “Balsam leading” stratum.

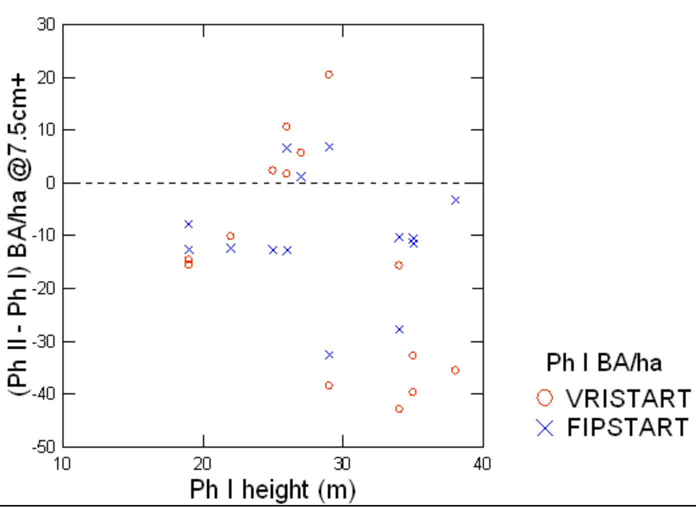

Fig H-15: “Fir leading” stratum.

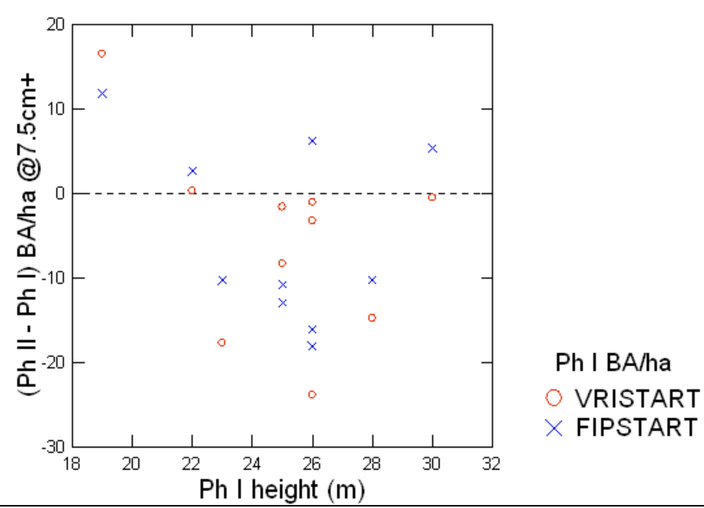

Fig H-16: “Other spp leading” stratum.

13. APPENDIX I: GRAPHS OF TOTAL VOLUME BIAS, MODEL BIAS & ATTRIBUTE BIAS

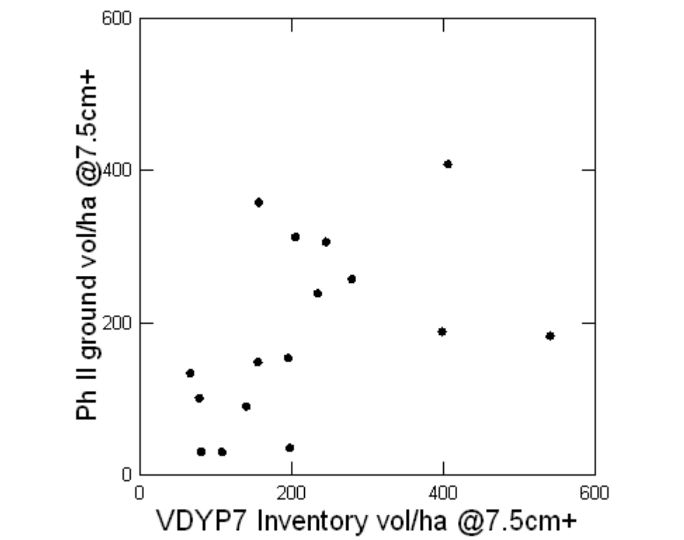

Fig I-1: Spruce leading stratum: ***"total volume bias"*** i.e. Phase II compiled vol/ha vs. VDYP7 Phase I inventory vol/ha.

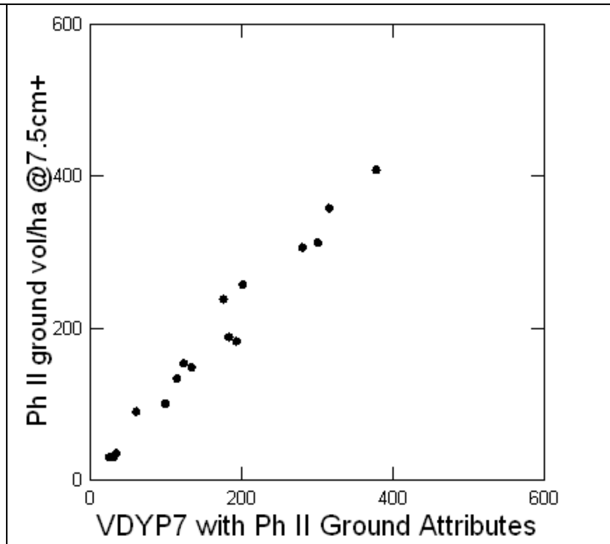

Fig I-2: Spruce leading stratum: ***"model-related volume bias"*** i.e. Phase II compiled ground vol/ha vs. VDYP7 vol/ha based on ground (Ph II) attributes.

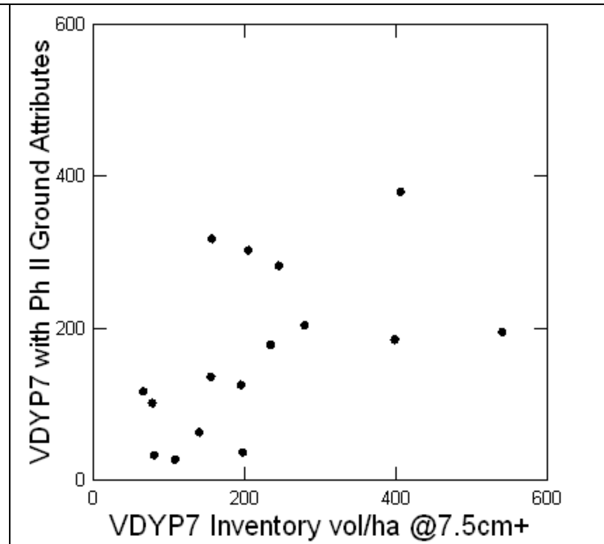

Fig I-3: Spruce leading stratum: ***"attribute-related volume bias"*** i.e. VDYP7 vol/ha based on ground (Ph II) attributes vs. VDYP7 Phase I inventory vol/ha.

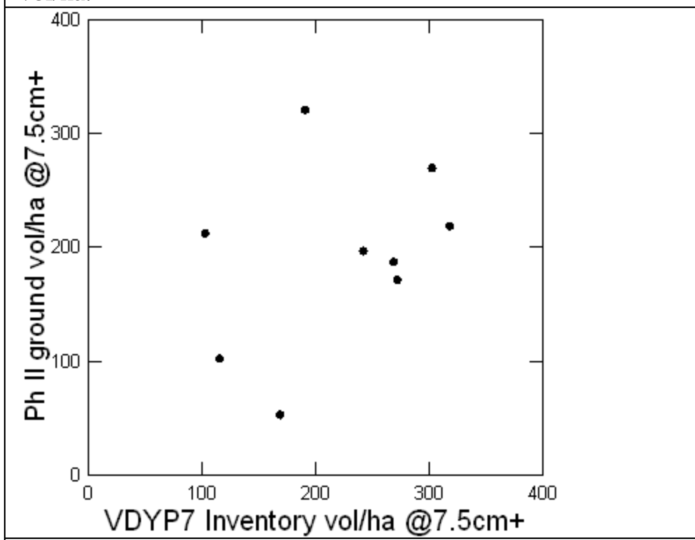

Fig I-4: Balsam leading stratum: ***"total volume bias"*** i.e. Phase II compiled vol/ha vs. VDYP7 Phase I inventory vol/ha.

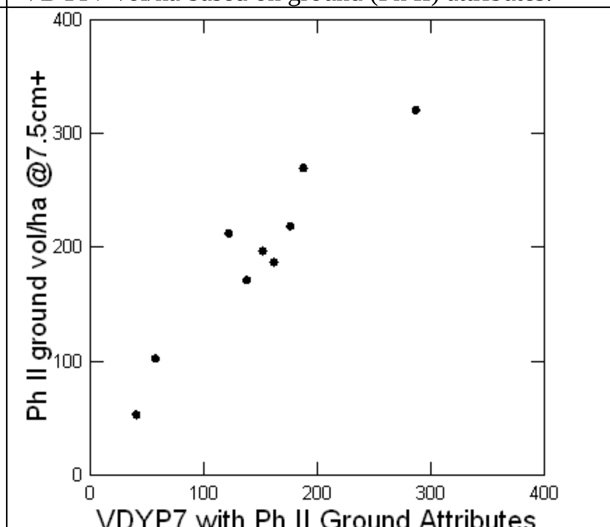

Fig I-5: Balsam leading stratum: ***"model-related volume bias"*** i.e. Phase II compiled ground vol/ha vs. VDYP7 vol/ha based on ground (Ph II) attributes.

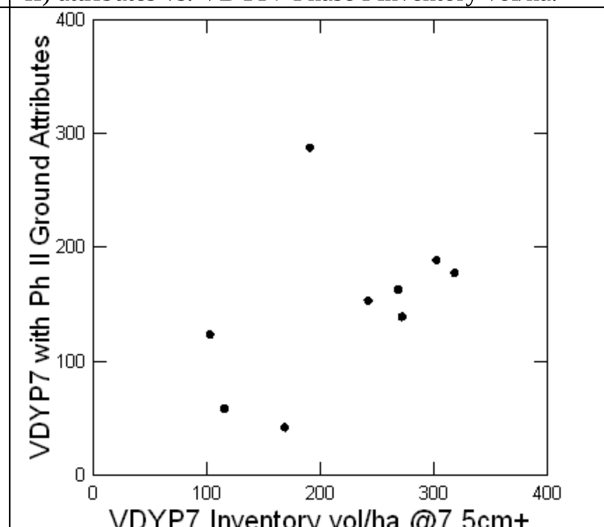

Fig I-6: Balsam leading stratum: ***"attribute-related volume bias"*** i.e. VDYP7 vol/ha based on ground (Ph II) attributes vs. VDYP7 Phase I inventory vol/ha.

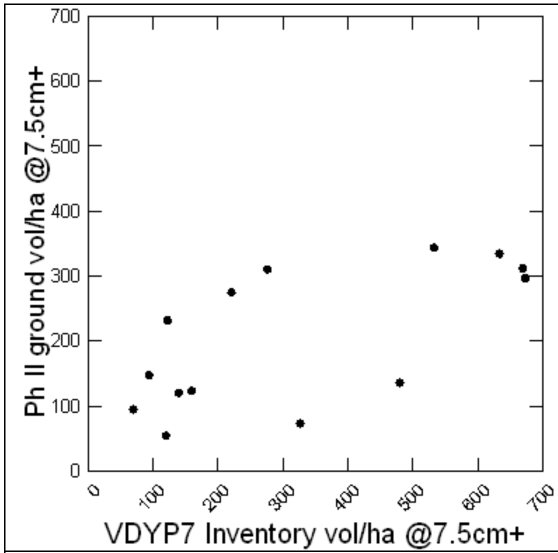

Fig I-7: Fir leading stratum: ***"total volume bias"*** i.e. Phase II compiled vol/ha vs. VDYP7 Phase I inventory vol/ha.

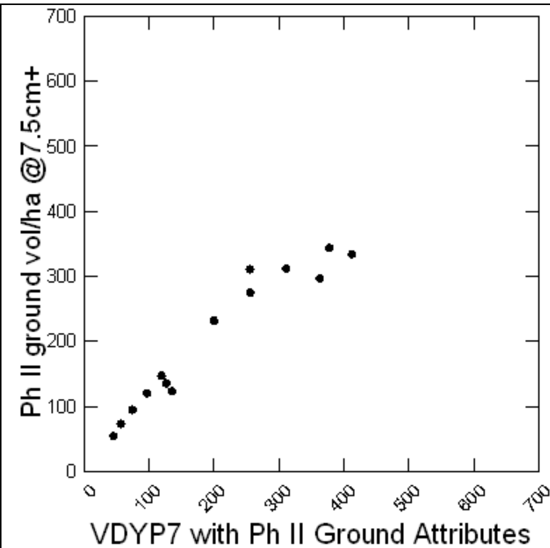

Fig I-8: Fir leading stratum: ***"model-related volume bias"*** i.e. Phase II compiled ground vol/ha vs. VDYP7 vol/ha based on ground (Ph II) attributes.

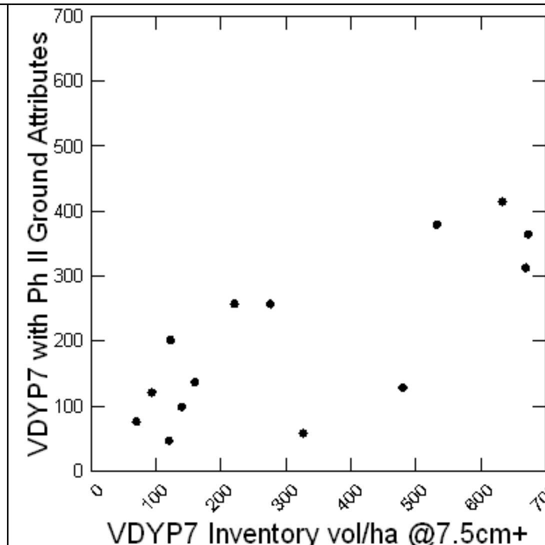

Fig I-9: Fir leading stratum: ***"attribute-related volume bias"*** i.e. VDYP7 vol/ha based on ground (Ph II) attributes vs. VDYP7 Phase I inventory vol/ha.

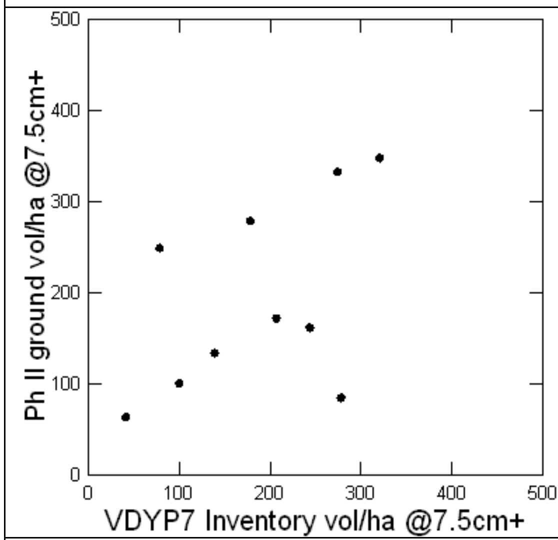

Fig I-10: Other spp leading stratum: ***"total volume bias"*** i.e. Phase II compiled vol/ha vs. VDYP7 Phase I inventory vol/ha.

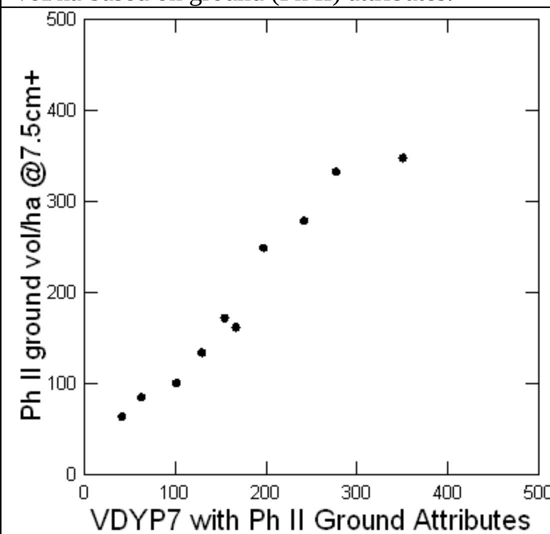

Fig I-11: Other spp leading stratum: ***"model-related volume bias"*** i.e. Phase II compiled ground vol/ha vs. VDYP7 vol/ha based on ground (Ph II) attributes.

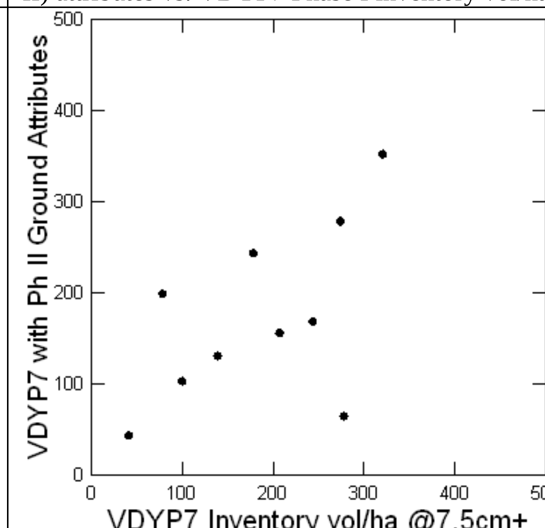

Fig I-12: Other spp leading stratum: ***"attribute-related volume bias"*** i.e. VDYP7 vol/ha based on ground (Ph II) attributes vs. VDYP7 Phase I inventory vol/ha.

14. APPENDIX J: SAMPLE SELECTION DOCUMENTS

QUESNEL TIMBER SUPPLY AREA
VEGETATION RESOURCES INVENTORY &
CHANGE MONITORING INVENTORY
GROUND SAMPLING:
SAMPLE PLAN

Prepared for:

Quesnel TSA Mitigation Committee

Prepared by:

Timberline Natural Resource Group Ltd.

Vancouver, BC

Project Number: BC0109331

May 2010

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

1.1 Background

The mountain pine beetle (MPB) began attacking the Quesnel Timber Supply Area (TSA) forests in 2001. Since then, the outbreak reached an epidemic, significantly altering the forest ecosystems within the TSA. The outbreak is subsiding and the impacted lodgepole pine (Pl) stands that remain are in a state of decay. The focus of the forest sector has been to salvage the dead Pl stands before they become uneconomic to harvest. The salvage window is closing and the focus will soon shift to harvesting non-Pl.

The Ministry of Forests and Range (MFR), Forest Analysis and Inventory Branch (FAIB) is leading Timber Supply Review (TSR4), with an expected allowable annual cut (AAC) Determination due in 2010. TSR5 is no more than five years away, and the AAC is expected to be significantly reduced.

The licensees and MFR are investing to improve inventory information to support TSR5. These initiatives include, but are not limited to:

- Developing a Predictive Ecosystem Map to better describe forest ecosystems in the TSA;
- Completing a Site Index Adjustment project to ensure that more realistic forest productivity estimates are used to grow stands in the forest estate model; and
- Completing an Economic Operability Assessment to define the economically operable timber within the TSA.

Approximately 70 percent of the TSA is covered by stands leading in Pl, much of which is now dead and decaying. The inventory labels used to describe these stands are no longer reliable and this erodes the confidence in timber supply forecasting. To improve the forest inventory information, the FAIB created a pilot program to assess ways in which the Vegetation Resources Inventory (VRI) can better describe the forests affected by MPB. A series of initiatives have been completed as part of this pilot program. Notably:

- An image based re-inventory test was completed on 10 mapsheets whose polygons were predominantly leading in Pl. The polygons were difficult to describe mostly because the imagery was poor and the generally grey colour of dead Pl stands. This program was completed in 2007.
- A VRI Phase I program was completed on 83 mapsheets in the east portion of the TSA on mapsheets that were predominantly mature green (ie, non-Pl leading). This program was completed in December 2009.

The next step is to design a field program that supports the key inventory information needs for TSR5.

1.2 Terms of Reference

This sample plan was completed for the Quesnel TSA licensees and the MFR, FAIB by Eleanor McWilliams, MSc, RPF (technical support), Hugh Carter, MSc, RFT (technical support) and Hamish Robertson, RPF (project manager) of Timberline Natural Resource Group Ltd. Gary

Johansen, RPF, Gordon Nienaber, RPF, Sam Otukol, PhD RPF of FAIB and Matt Makar, RPF of FAIB worked directly with Timberline staff to develop the methods contained in the sample plan.

1.3 Goals and Objectives

The primary goal of the overall program is to provide a level of comfort (reduced risk for decision makers) on the actual volumes and health of stands on the Quesnel TSA. The objective of this program was to:

1. Determine the key inventory business needs for the TSA to support TSR5;
2. Develop flexible sample designs for each of the strata;
3. Describe the proposed field program for post-harvest and regenerated (PHR) stands;
4. Describe the proposed field program for stands that underwent VRI Phase 1 in 2009 (generally described as mature green stands);
5. Identify potential inventory options for the area not included in the 2009 VRI Phase 1 program (generally described as dead-Pl); and
6. Document the proposed implementation program.

2.0 BUSINESS NEEDS ASSESSMENT

2.1 Business Needs Consultation

The key stakeholders identified in this initiative are:

- The Quesnel TSA licensees; and
- MFR (FAIB and Southern Interior Forest Region).

The licensee representatives were Earl Spielman, RPF (West Fraser Mills Ltd.)[1] and Phil Winkle, RPF (DecisionTree Forestry on behalf of C&C Timber). A preliminary list of inventory business needs was developed in February 2009 for natural and post-harvest and regenerated (PHR) stands within the Quesnel TSA.

Timberline staff met with MFR representatives in June 2009 to review and update the inventory business needs for the TSA. MFR representatives included Albert Nussbaum RPF, Gary Johansen RPF, Gordon Nienaber RPF, Jon Vivian RPF, Atmo Prasad RPF, Matt Makar, RPF, Chris Mulvihill RPF, and John Wakelin RPF. At this point, it was determined that Timberline would work directly with Gordon Nienaber and Matt Makar in designing the Quesnel program.

2.2 Primary Business Needs

The business needs focused on developing improved inventory information for TSR5. For planning purposes the landbase was divided into three key strata: mature green leading, dead-Pl leading, and PHR stands. The business needs identified are:

1. Determine the area, distribution and merchantable volume in mature green leading stands. The mature green component is generally regarded as the key strata in the short- and mid-term timber supply forecast.
    a. Complete the VRI Phase I on the mature green leading stands to current standards (completed December 2009).
    b. Assess the accuracy of the inventory estimates using VRI timber emphasis plots to complete an inventory audit style approach.
2. Update the inventory attribute information for MPB attacked stands to better reflect their current condition. A key decision for TSR5 will be how stands attacked by MPB are described and modelled in the yield curves. For those stands that will not be harvested, information about Pl mortality rates and the size, health, vigour and distribution of remaining live stems will be key components to creating yield curves for these stands. In particular:
    a. Identify the percentage of Pl that survived the attack.
    b. Identify year of death for MPB killed stands.

[1] West Fraser initiated a CMI program on TFL 52 in 2001 and has completed two measurements (2001-2003 and 2006 -2008) on 82 plots since then.

   c. Develop shelf-life projections for dead Pl.
   d. Project the non-Pl portion of the stands forward to the projection date for TSR 5.
   e. Develop projections of regeneration in non-salvaged MPB attacked stands.

3. Determine the actual growth of PHR stands to ensure that they are growing as projected in TSR.
   a. Determine MPB loss in Pl-leading PHR stands. Previous analyses assumed all stands less than 60 years old were not attacked.[2]
   b. Monitor the growth and yield of all PHR and naturally regenerating stands.
4. The sampling program should incorporate both Provincial (i.e., BC-National Forest Inventory [NFI]) and management unit information needs to best utilize inventory program investment.

[2] This is known to be incorrect. This information needs to be updated (the 2006 Type 2 Silviculture Strategy assumed 80% of managed Pl stands would incur a 30% volume loss).

3.0 SAMPLE DESIGNS

3.1 Overview

The program to address the identified business needs is described in the following three sections. Each section describes details of the sampling program proposed for that stratum. The three key strata are:

- PHR stands – all PHR stands between 15-47 years in the Forest Management Landbase (FMLB). This is the stratum where a Change Monitoring Inventory (CMI) program will be implemented using an intensification of the NFI grid.
- Mature green stands – these stands are largely those that are 48 years and greater and are not leading in Pl. The VRI Phase I program was implemented on 83 mapsheets, within which this stratum all resides. A VRI Phase II plot program will be implemented in this stratum to quantify the risk associated with the new Phase I inventory attributes. These plots are established so that they can be re-measured in future, if necessary.
- Dead-Pl - All Pl leading stands greater than 47 years in the vegetated-treed landbase that were delineated to Phase I standards (83 mapsheets), as well those mapsheets that did not have a VRI Phase I completed. A low intensity monitoring program is proposed for this population.

3.2 Data Assumptions

The sampling programs developed used the following principles and assumptions:

1. The inventory data used to derive the PHR program was downloaded from the LRDW March 10, 2009 and updated with harvest information.[3]
2. The December 2009 VRI Phase I data was used to derive the Mature Green program. This data was not validated by MFR but was acceptable to expedite the sample selection process.[4]
3. The NFI 20 km grid was chosen as the platform so that a subset of any grid size chosen will be NFI 20 km grid points. Where appropriate, BC-NFI plots should be installed across the entire TSA to support FAIB reporting needs.[5]

[3] Gordon Nienaber, RPF, TSR4 timber supply analyst provided the harvest information and landbase definition on August 9, 2009.

[4] Use of this dataset was discussed with and approved by Gary Johansen in February 2010.

[5] Forest Analysis and Inventory Branch will provide the additional funding to complete plots to full BC-NFI standards.

4.0 PHR STAND SAMPLE DESIGN

4.1 Overview

The CMI sample design provides a set of representative sample points from a 5-km grid across PHR stands on the Quesnel TSA. The grid size was chosen to generate 50–100 points in PHR stands between 15 and 47 years of age in the first measurement period. This design will provide data to compare G&Y for all PHR stands in aggregate[6] and for Pl-leading stands (the most predominant). The sample size is not large enough to separately check G&Y estimates for stands with other leading species. The sample plots are 400-m^2 fixed-area permanent sample plots (PSPs). The measurements will follow NFI-BC standards and procedures[7] with some minor variances (Section 4.8). The intent is to remeasure the plots every five years, however, this and other elements of the CMI can be changed over time as necessary.

4.2 Objectives

The primary objectives of the CMI program are to:

1. Monitor the change in merchantable volume over time and compare this to predicted values used in timber supply analysis;
2. Check absolute values and stability of site index estimates over time and compare these to the values assumed in timber supply analysis;
3. Compare CMI plot data against selected inventory attributes and timber supply assumptions to detect relevant differences; and
4. Monitor and report on any forest health issues.

The secondary objectives of the CMI program are to:

1. Support certification requirements;
2. Provide information to the Provincial Government climate change reporting initiative;
3. Provide data to check that accurate inputs are being used in forest carbon projections; and
4. Use a flexible design that can be modified for future potential information needs.

4.3 Target Population

For the purposes of defining the PHR target population, stands were categorized into four species classes: Pl-leading, Conifer (non-Pl) -leading, Deciduous-leading and Unknown (no data) based on the greatest percent composition in the species label. Thus, a stand was Pl-leading if it was

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[6] The question being asked is: over the entire TSA, are PHR stands on average growing as expected?

[7] BC Ministry of Sustainable Resource Management March 2005. National Forest Inventory – British Columbia. Change Monitoring procedures for provincial and national reporting. Version 1.4. 208pp. + appendices. (http://ilmbwww.gov.bc.ca/risc/pubs/teveg/nficmp05/nfi_cmp_2k5.pdf)

34% Pl, 33% Conifer, and 33% Deciduous. Stands were categorized into four age classes: Regen (0-14 years), PHR (15-47 years), Mature (48 years +), and Unknown (no data).[8]

The target population was defined using the Forest Managed Landbase (FMLB) with ages projected to 2009. The target population is all PHR stands between 15 and 47 years of age (since disturbance) in the FMLB. This age range is used to limit sampling to stands that have merchantable volume (thus the minimum of 15 years) and that are of post-harvest origin (thus the upper limit of 47 years). The target population can expand over time as new stands grow into the population definition, though the target population definition may change in future as business needs change.

4.4 Sample Location

A 5-km grid will be used to locate CMI plots over the target population. Plots will be systematically located in part because they cover practically as many conditions as random plots and are convenient since plot locations are automatically known once the grid size is defined.

4.5 Sample Size

The 5-km grid provides 61 plots in PHR stands as of 2009 and up to 132 PHR plots after 15 years (Table 1) (Appendix II).[9,10] The sample size is determined by the grid spacing and the area targeted for sampling in the target population area. The two main criteria influencing the choice of grid size is the sample size that will be achieved in the target area today, and how this sample size will increase over time as the target area expands (i.e., as natural stands are harvested, regenerated, and included in the PHR target population).

Table 1. Summary of 5 km grid points by leading species and age class.

	Age Class		
Leading Species	PHR (15-47)	Regen (0-15)	*Total*
Conifer	15	8	*24*
Deciduous	5	2	*7*
Pl	41	45	*87*
Unknown	0	15	*15*
Total	*61*	*70*	*132*

[8] The inventory data used was downloaded from the LRDW website March 10, 2009 and was updated with harvest information provided by Gordon Nienaber August 9, 2009. The FMLB definition along with ages projected to 2009 were used to define the target populations and is assumed to be the best available information. Any errors in this data will translate to errors in the summaries presented.

[9] One point already has a BC-NFI plot leaving 60 plots to be established.

[10] Prior to the second measurement the business needs and sample design will be reassessed and updated in a sample plan that will be submitted to MFR for review and approval.

4.6 Plot Design

The plot design follows the NFI-BC protocol for tree attributes (Figure 1). The main plot is 400 m^2 (11.28 m radius) where all trees greater than 9.0 cm are measured and tagged. Trees between 4 and 9 cm are measured and tagged in the small tree plot (100 m^2, 5.64 m radius), and all trees less than 4 cm dbh and greater than 30 cm tall are counted in the regeneration plot (19.6 m^2, 2.50 m radius). Some modifications to the standards have also been implemented (listed below).

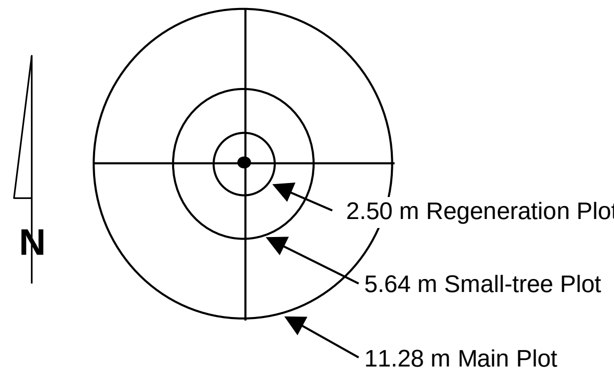

Figure 1. CMI sample plot.

4.7 Remeasurement Period

We recommend a five-year re-measurement period, or as appropriate for the information needs of the Quesnel TSA. A 10-year re-measurement period has a high risk of plots being damaged and data lost.

4.8 Plot Measurements

4.8.1 Overview

The NFI-BC plot protocol will be used. Information that will not be collected includes:

1. Ecological data plots (10 m radius). However, a visual estimate of the biogeoclimatic site series will be recorded on the Ecology Header (EH) card.
2. Forage production micro plots.
3. Soils data.
4. Old growth data.

Protocols that will be modified include those for tag placement, coarse woody debris (CWD), photos and site tree selection as described below.

4.8.2 Plot Establishment

Navigation to the plot and establishment methods will follow the NFI-BC standards and procedures.

4.8.3 Tree Tags

Blue tree tags will be affixed at breast rather than at stump height as recommended in the protocol. This should simplify the work without making the plot unduly visible.

4.8.4 Plot Cards

The MFR VRI plot cards will be used for the CMI sample (as they are used for the NFI-BC). Some modification of the VRI cards is needed to accommodate information that is not taken in VRI (e.g., information on more site trees, quadrant of main plot, etc.).

4.8.5 Top Height Tree

The height and age of the largest diameter tree (regardless of species) in the NE quadrant will be measured and recorded as per the standard. This tree is the top height tree as identified in the standards and will be recorded as the "T" tree.

4.8.6 Site Trees

The height and age of the largest diameter tree of each species in each quadrant will be measured. These trees will be coded temporarily as "O" trees and will be recorded as required if they do or do not have suitable height and age measurements. The leading and second species will be determined and the site trees for the species will be changed from "O" to "L" and "S" trees prior to data entry into TIMVEG. "O" trees in TIMVEG are only "other species" (not "L" or "S" species) that are more than 20% of the plot basal area.

If the largest diameter tree of a given species is not a suitable site tree, the next largest diameter tree will be assessed for both suitable height and age. If acceptable for estimating site index, height and age will be recorded and this tree noted as "X" tree. If the second largest diameter tree is not acceptable, no further measurements will be taken. "V" trees are a representative residual tree from the 11.28m plot if present. "T" trees will be the top height from the 5.64 fixed radius plot. This procedure produces more height and age measurements and also ensures that all data required under the standard is collected. Using this approach, only "X" trees can be step-down trees.

If a site tree is between 4 and 9 cm and in the 11.28 m radius plot, but outside the 5.64 plot it will be tagged.[11]

4.8.7 Coarse Woody Debris

CWD transects will be done to NFI-BC standards, with one exception. On the last 10 m only pieces 7.6 cm and larger will be measured. So the procedure will be modified slightly from section 8.1 in the NFI-BC manual (modifications **highlighted**):

1. Establish the first line at a pre-assigned random azimuth from the IPC.
2. Measure out along the random azimuth with a tape to 30.0 m, correcting the distance to horizontal.
3. **Mark both ends of the transect with pins**.
4. Mark along the line with logging paint the intersection of the line transect with potential small and coarse woody debris.

[11] Trees between 4 and 9 cm diameter are not normally tagged in the outer "donut" of the 11.28 m plot.

5. Number a few of the large CWD with log marking paint to aid re-measurement and quality control.
6. Establish the second line at plus 90° from the first transect commencing at the IPC.
7. Record the azimuth of each line on the Coarse Woody Debris (EW) and (EC) Field Cards.
8. Measure the following pieces of coarse and small woody debris along the transect:
    a. From the IPC to 10.0 metres measure all CWD greater than 30.0 cm.
    b. **From 10.0 metre to 30.0 metres measure all CWD equal to or greater than 7.6 cm.**

4.8.8 Photos

If possible, crews should take at least one generic plot photo and one that shows the area around the IPC to help future re-location if necessary.

4.9 Data Management

Data entry, error checking and management will use the same processes used for the NFI-BC plots.

4.10 Analysis & Interpretation

The overall goal of the CMI analysis is to determine whether any significant differences exist between the attributes measured in the field and those modelled in timber supply (i.e. "are the timber supply analysis assumptions reasonable?"). The CMI analysis results serve as an early warning system should the modelled assumptions not be achieved on the ground.

Point in time estimates of site index and merchantable volume will be provided after the first measurement. These estimates can be compared to the values assigned to the forested polygons where the plots land. Change can be estimated when two or more measurements are completed and differences between the measured and predicted attributes of interest can be estimated. Graphical analysis will include plotting actual versus predicted values and plotting differences (actual-predicted) versus stand age or any other chosen variables to examine trends. The statistical analysis will include the average differences and associated confidence intervals.[12]

The graphical and statistical analysis methods are intended as tools to examine the data for possible overall trends of over- or under-prediction – these analyses are not meant as definitive tests. If the analyses suggest over- or under-prediction, then possible sources of the differences should be identified. For example, when considering volume estimates, potential factors to consider as sources of mean error are the differences between the inventory inputs to the model and the actual stand attributes. Potential inventory attributes to examine include stocking, site index, treatment, species composition, stand structure, and pest or disease incidence.

[12] The specific features to be analyzed will be discussed with MFR prior to analysis.

When using models for prediction there are two main sources of error. The first is errors within the model; the model produces inaccurate results despite being supplied with accurate inputs. When developing models, the modelers use model validation techniques to minimize these errors. Model validation often uses data from plots purposely located across a range of conditions (response surface) to ensure the model is performing correctly. The second is model application error. Model application error can result from incorrect inputs being supplied to the model or model results being extrapolated to situations the model has not been calibrated for. If, for example, the monitoring data detects significant differences between the merchantable volumes predicted for a specific stand type and that observed on the ground, the differences could be due to model errors, or model application errors. The intent of the analysis is to "raise a red flag" that something is wrong. Given the limited sample sizes, and the inability of the sampling design to definitively determine cause and effect, the ultimate cause of the problem may not always be discernable from the monitoring data. However, previous experience in analyzing CMI data has demonstrated that when significant prediction errors are present it is due to incorrect inputs such as species, stand initialization planting versus natural), and potentially OAFs not correctly reflecting insect and disease damage.

4.11 Future Modifications

Prior to the second measurement, the business needs and sample design will be revisited. Any changes will be updated in the sample plan and submitted to MFR for approval. Future modifications to the CMI program could include:

1) **Managing sample size**

   The CMI target population will increase as more natural stands are harvested, regenerated, and brought to the minimum age of 15 years from disturbance. Though the target population will grow, the future sample size can be increased or decreased based on the business needs at that time.

2) **Increasing measurement period**

   The five-year measurement period has traditionally been recommended because it corresponds with the TSR schedule and there is limited risk that plots will be damaged or data lost. However, this recommended time interval could change if the there is a higher level of comfort in PHR yield estimates, or if program costs need to be decreased. The advantage of an increased measurement period is lower costs, however, the disadvantage is that less information can be obtained from the data, and linking previous measurements will be more complicated.

3) **Expanding the CMI program to naturally regenerated stands**

   Currently this proposed program focuses on post-harvest stands. Given the MPB attack there will be naturally regenerating stands on the TSA that should be observed. Whether or not these stands are sampled in the future under this program or under the umbrella of sampling the mature Pl is largely an issue of semantics.

4) **Expanding the program into older stand types**

   The need to monitor carbon stocks on a management unit is emerging as a business need. The CMI program design is perfectly suited to provide statistically valid estimates of carbon stocks across a management unit. In these instances, a plot program is expanded outside the traditional CMI target population, but likely with a far reduced sampling intensity.

5) **Adding other information**

New tree measurements can be added to the CMI program at any time in the future. For example, measurements of branch size, tree taper, or wood quality could be included in the next measurement cycle. This would provide the same representative sample, but change estimates could not be computed until two or more measurements of the same attribute were taken.

5.0 MATURE GREEN SAMPLE DESIGN

5.1 Overview

The mature green stratum will provide the majority of short- and mid-term timber supply in TSR5, and is the most important strata. Therefore, it is vital that the inventory estimates describing stands in the mature green be reliable. A moderate degree of uncertainty in the inventory attributes can create a high degree of uncertainty in the timber supply forecast.

A new VRI Phase I was completed in December 2009. The business need is to determine the area, distribution, and merchantable volume in mature green leading stands and to obtain a precise ground based estimate of the volume in these stand types.

5.2 Objectives

The objective of the mature green sampling program is to assess the accuracy of the inventory using VRI timber emphasis plots.

5.3 Landbase Netdown

The 83 mapsheets recently completed as part of the VRI Phase I program represented approximately 707,000 ha (Table 2). The majority of the land base is between 100 – 250 years of age. Table 3 shows the species and age distribution within the TSA as represented by the portion of the target population as defined in Section 5.4.

Table 2. Quesnel VRI Phase I target population net down

Land Classification	Area	% of TSA
TSA (83 mapsheets)	***706,748***	***100.0***
TFLs (52 and 53)	78	0.0
Indian Reserves	2,727	0.4
Parks	2,112	3
Woodlots and Community Forests	44,607	6.3
Maps in West of TSA (16)	166,992	23.6
Area of Interest (67mapsheets)	***490,231***	***69.4***
Pl Leading	72,988	10.3
Stands < 48 years (in 2009)	149,270	21.1
Non Vegetated Treed	15,957	2.3
Target Population	***252,017***	***35.7***

Table 3. Species distribution by MFR age class as % of target.

	Age Class							
Species	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
S	0.8	1.2	2.8	4.5	7.4	15.2	1.7	33.5
Fd	1.5	2.8	4.8	6.2	8.4	5.7	0.3	29.7
Bl	0.1	0.3	0.4	0.9	1.2	11.9	0.4	15.2
At	0.8	1.9	4.0	5.2	1.9	0.2	0.0	13.9
Ep	0.3	0.7	1.8	1.6	0.5	0.0	0.0	4.9
Cw	0.0	0.0	0.0	0.0	0.0	0.6	0.6	1.2
Act	0.1	0.0	0.1	0.3	0.3	0.2	0.0	1.0
Sb	0.0	0.1	0.1	0.1	0.0	0.1	0.0	0.3
Hw	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.3
Total	***3.6***	***6.9***	***13.9***	***18.8***	***19.9***	***33.9***	***3.0***	***100.0***

5.4 Target Population

The mature green stratum target population was defined as those polygons in the 67 mapsheets of interest where:

- Pl was not the leading species,
- Stands were 48 years[13] or older in 2009
- Polygons were vegetated-treed as defined by the BC land classification system (Table 4, Figure 2).

Table 4. Quesnel TSA mature green target population.

Land Classification	Area	% of TSA
Area of Interest (67 mapsheets)	***490,231***	***69.4***
Pl Leading	72,988	10.3
Stands < 48 years (in 2009)	149,270	21.1
Non Vegetated Treed	15,957	2.3
Target Population	***252,017***	***35.7***

The target population represents approximately 252,000 ha (or 36% of the area where the Phase I was completed [83 mapsheets]).

5.5 Stratification

Stratification of the target population improves the sampling efficiency by grouping similar sub-populations that might exist within a general population. Strata were created based on similarity of sub-populations while considering the number of samples being established. Using these criteria, the target population was stratified based on age (Table 5). The strata were defined as follows:

Table 5. Quesnel TSA mature green stratification.

Stratum	Sub - Stratum	Area (ha)	%	
			Target	**Stratum**
Young (48-120 yrs)	S & Bl	27,677	11%	25%
	Fd	38,404	15%	35%
	Other	42,773	17%	39%
	Total	108,854	43%	100%
Old (121 yrs+)	S & Bl	95,249	38%	67%
	Fd	36,335	14%	25%
	Other	11,579	5%	8%
	Total	143,163	57%	100%
Total		***250,017***	***100%***	

1. Young – Those stands in the target population between 48 and 120 years in 2009.
2. Old – Those stands in the target population greater than 120 years of age in 2009.

Final analysis results will be reported at the stratum level, and the strata may change based on the data and the variability observed during the analysis.[14] The strata were subdivided into sub-strata to ensure a representative distribution of samples within each stratum. The sub-strata were based on species group using the species that were most abundant and/or most important for future timber supply in the area. Sub-stratification is critical for spatial distribution of plots.

[13] The CMI target population included stands 15 - 47 years in 2009. The VRI and CMI target populations do not overlap.

[14] Upon examination of the final data, some post stratification may be necessary. Decisions regarding appropriate analysis scenarios will be discussed with MFR and TSA stakeholders.

Analyses will use the substrata level information for variance and means calculation and be rolled up, using the appropriate weights, for reporting at the stratum level. The results will be applied at the stratum level as these sampling groups have sample sizes that allow for the most meaningful results.

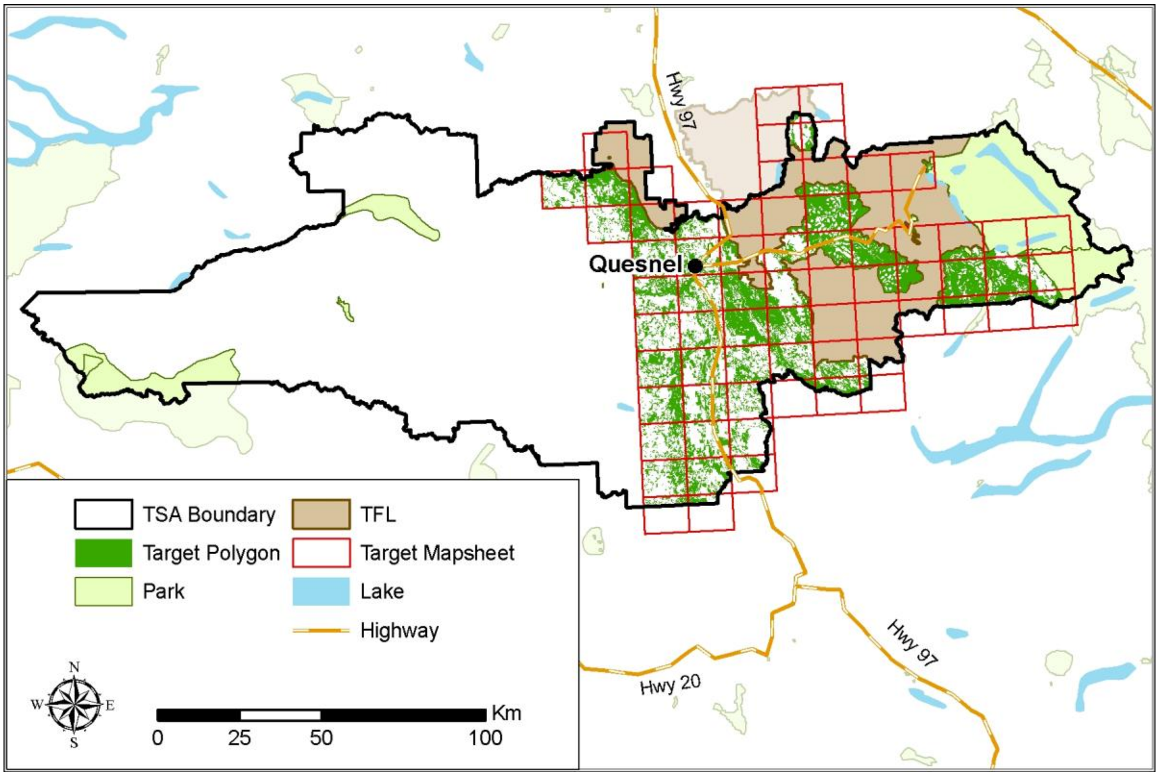

Figure 2. Quesnel TSA mature green target population distribution.

5.6 Phase II Program

5.6.1 Sampling Objectives

The primary objective is to install 50 samples in the target population to determine whether a sufficient level of comfort exists to use the Phase I in TSR5.

Sampling will follow a two-pass approach, whereby the first batch of 50 samples will be installed and an interim analysis will be completed. If the results appear reasonable, no further sampling is required.[15]

If significant differences exist between the Phase I and Phase II plot estimates, a second pass will occur and additional samples will be installed in the target population. If, after the second batch is installed, there are still significant differences between the Phase I attributes and Phase II ground

[15] The MFR and lead proponent will determine whether additional samples are required.

plot data, a decision will be made in conjunction with MFR to accept the differences, or statistically adjust the Phase I attributes with the Phase II ground sample data.

5.6.2 Sample Selection

Sample polygons were selected using probability proportional to size with replacement (PPSWR). Each polygon in the target population was listed once and size was total area of the polygon. The sample points within the sample polygons were selected from the provincial 100m grid in the Geographic Information System (GIS) using the simple random sampling (SRS) method. Appendix III lists the 50 samples with their locations and label for NVAF enhancement.

5.6.3 Sample Size

Fifty (50) samples were selected from the target population and will be installed in the two strata. The sample distribution is approximately equal to the area distribution of the strata. Twenty (20) samples will be established in the Young stratum and 30 samples will be established in the Old stratum (Table 6).

Table 6. Quesnel TSA mature green sample size by stratum

Stratum	Sub - Stratum	Area (ha)	No. Plots	Sampling Weight (ha)
Young (48-120 yrs)	S & Bl	27,677	5	5535
	Fd	38,404	7	5486
	Other	42,773	8	5347
	Sub-Total	***108,854***	***20***	***5443***
Old (120 yrs+)	S & Bl	95,249	20	4762
	Fd	36,335	8	4542
	Other	11,579	2	5790
	Sub-Total	***143,163***	***30***	***4772***
	Total	***250,017***	***50***	***5,000***

The sample and target population were compared by all variables potentially adjusted for, and used in VDYP7 including: height class, age class, basal area class, density class, Lorey height class, and volume class (Appendix IV).

The distribution of the sample best represents the age class, volume class, Lorey height class, and stems per hectare class distributions of the target population. The sample does represent the height class distribution; however the 20m and 35m classes are slightly over-represented and the 15m class is slightly under-represented. The sample also represents basal area distribution within the target population; however the $10m^2$/ha will have a high intensity of plots and the $40m^2$/ha class will have a low intensity of plots.[16]

[16] While it is ideal that a sample represents the distribution of all variables of interest, it should be expected that some classes in some variables would have slight skewing of distribution when drawing a random sample of a small size. The sample distributions for height class and basal area class pose a small risk to the outcome of the overall Phase II program and the sample does represent the target population well for four of six variables of interest.

5.7 Net Volume Adjustment Factor Sampling

One VRI plot for every three trees destructively sampled will be enhanced to provide information for developing the NVAF tree matrix. Typically the NVAF target sampling error for live tree volume was ±7.5% (95% confidence), however the intent of this program is simply to provide a level of comfort and not attempt to achieve a target sampling error.

Table 7. NVAF maturity and weights.

Maturity	Area (ha)	Plots	Plot weight (ha/plot)
Immature	108,854	5	21,771
Mature	143,163	8	17,895
Total	***250,017***	***13***	***19,232***

Thirteen (13) VRI Phase II plots (5 immature and 8 mature)[17] (Table 7) were selected to be NVAF-enhanced (one plot for every three trees being destructively sampled). The VRI Phase II plots were sorted by NVAF stratum and sub-stratum and plots were selected using a systematic sampling design with a random start. Net-factoring and call-grading will be completed on all auxiliary plots for the NVAF-enhanced plots.

The NVAF sample size and species distribution will be finalized following review of the Phase II field data. All trees will be selected following the MFR standards at the time of selection.

5.8 Field Implementation

5.8.1 Sample Packages

Field sample packages include at a minimum:

1. An ortho-photo (1:5,000) showing plot location and its GPS points;
2. An ortho-photo (1:10,000) showing plot location and access;
3. A forest cover map (1:10,000) showing target polygon and plot locations with roads, contours and water features.
4. Overview map (approx 1:100,000) for general polygon location.

5.8.2 Field Crews

A project pre-work meeting will be held on the first day and sampling should begin immediately thereafter. All plots will be installed at the random locations selected by the GIS. If a plot location is unsafe or is no longer part of the target population (due to harvesting or fire), the project manager will work with the MFR representatives to locate an alternate location. If an alternate location cannot be found, the plot will be dropped as per ground sampling procedures at the time of contract signing.

[17] Stands 48 to 120 years in 2009 were considered immature. Stands 121+ years were considered mature.

5.8.3 VRI Measurements

The project priority is to measure timber attributes and CWD at each plot. Data will be collected to provincial VRI ground sampling standards at the time of contract signing. Additional attributes beyond VRI requirements will be measured. Certified crews will gather the data using VRI Card Types 1, 2, 3, 6, 7, 8, 9, 10, and 11.

5.8.4 Non-Standard VRI Data

Additional, non-standard VRI data will be collected to supplement the information normally provided by the VRI Phase II sampling. Collection of this data will allow the plots to be re-measured over time, should this re-measurement become an inventory priority. Additional measurements will include:

1. Measure the distance from the sample point to the tree in the auxiliary plots.
2. Measure the distance from the sample point to trees just outside the auxiliary plots.

5.8.5 Core Counting

Tree ages from sample cores will be counted by the field contractor completing the plot. Ages will be counted in the lab using a microscope and entered into the MFR data entry program, TIMVEG.

5.8.6 Data Entry

Standard VRI field data will be entered into the MFR data entry program TIMVEG. Validation reports will be generated for each plot to ensure data integrity. All standard VRI data will be provided to the MFR to be included in the provincial VRI database. Non-standard data will also be provided to the MFR in a digital format.

GPS data will be post-processed by the field contractors.

5.8.7 Pre-work and Quality Assurance

All field crews should attend a pre-work session with the client and auditor to review the plot methods and ensure that all questions are resolved at the beginning of the project. The client will hire a Phase II certified third party auditor to audit a minimum of 10% of all plots following the VRI Ground Sampling Quality Assurance Standards at the time of contract signing. Auditing will be done by batch, and failed plots may result in a failed batch. Crews may be required to revisit failed plots at their own expense.

5.8.8 Plot Supplies

Supplies such as aluminum stakes, field maps, field equipment, photos, plot cards, handheld data recorders, GPS units, and other required equipment will be supplied by the field contract crews. The MFR will supply VRI tags for each sample.

5.8.9 Net Volume Adjustment Factor Sampling

Upon completion of the 50 Phase II plots, all trees in the NVAF-enhanced plots with a diameter at breast height 12.5 cm or larger will be included in the sampling frame to develop the tree matrix. The proposed strata for the NVAF program are as follows (no dead trees will be sampled):

1. Immature – 48 to 120 years in 2009.
2. Mature – 121+ years in 2009.

The MFR Volume and Decay Officer assigned a sample size of 40 trees based on the species distribution in the target area (Table 8). Once the tree list is finalized a NVAF-certified crew(s) will be hired to complete destructive sampling.

Table 8. Preliminary NVAF sample size[a]

Stratum	Spp	% of Land base		No. Trees	
		Total	Group	Total	Group
Immature	S & B	11	25	4	25
	Fd	15	35	5	35
	Other	17	40	6	40
	Total	***43***	***100***	***15***	***100***
Mature	S & B	38	67	17	67
	Fd	14	24	6	25
	Other	5	9	2	8
	Total	***57***	***100***	***25***	***100***
Total		***100***		***40***	

[a] The distribution was based on the area represented by each species and will likely vary once the field data is collected and analyzed.

The NVAF program will follow MFR VRI standards at the time of contract signing, which likely includes five steps:

1. Create a tree matrix using data from the enhanced Phase II plots.
2. Select sample trees from the tree matrix.
3. Complete stem analysis of the sampled trees.
4. Complete a third-party audit of the sample trees.
5. Analyze the data to develop net volume adjustment factors.

The client will hire a third party auditor to audit a minimum of 10% of all trees following NVAF quality assurance standards at the time of contract signing.

5.9 Inventory Assessment

5.9.1 Data Compilation and Analysis

The licencees will use the MFR SAS compiler to compile all Phase II plots and NVAF trees and will complete the Phase II data analysis. This analysis will:

- Use an approach similar to the Inventory Audit Procedures (or equivalent) for comparing estimates of volume to determine if there are significant differences between the key inventory attributes.
- Calculate ground sample average volumes and inventory volumes for the target population.

If required, use the VRI Interim Procedures and Standards for Statistical Adjustment of Baseline VRI Timber Attributes, including:

- Adjust inventory height, age, basal area, and stems per hectare.
- Generate new VDYP7 volumes using the adjusted attributes.
- Adjust ground volumes using NVAF ratios.
- Adjust new volume estimates and Lorey height with the NVAF-adjusted ground volumes using the ratio of means method.
- Compute sampling errors and complete significance tests for the Quesnel TSA.

The ground samples were selected using recently completed Phase I data that had not been processed by the MFR. This was done to expedite the sample selection process. At the time of final adjustment the most recent data available will be used. It is anticipated that the data will have been processed by the MFR at this time and will be available through the LRDW.

5.9.2 NVAF Analysis and Ratio Calculation

Upon completion of the destructive sampling program, data analysis will be completed and new NVAF ratios will be generated. All NVAF stem analysis will follow the MFR standards and the "model based" approach for generating the ratios will be used as the samples were selected with approximately equal intensity by stratum.

6.0 DEAD PL SAMPLING OPTIONS

6.1 Background

The PHR and mature green programs detailed in this sample plan cover approximately one-third of the TSA area; the remaining area is within the "dead-Pl" stratum (approximately 700,000 ha).[18] This stratum is where the MPB epidemic caused the greatest change to the forests and is where the majority of the Pl salvage has occurred. As a result of these two factors, this is also the area where the inventory labels used to describe the forest characteristics are very unreliable.

The dead-Pl stratum is likely to have short-term relevance in TSR5 as it continues to support the short-term AAC. This diminishes significantly in the mid-term timber supply forecast which becomes sustained by the mature green stratum and, increasingly, the PHR stratum.

The challenge is to develop a program that addresses the short-term information needs of existing forest licensees, TSR5 information needs, and future investment needs from the forest resource with increasingly scarce financial resources.

6.2 Proposed Program

Stands within the dead-Pl stratum will undergo a high degree of change over the next few decades. These stands will be characterized be a mix of standing mature non-Pl, large areas of decayed Pl and an increasing presence of understory. Timber supply modelling efforts continue to incorporate gross assumptions around shelf-life and crude attempts at describing stand dynamics. The end result is a high degree of uncertainty in existing and future stand types.

Completing a traditional Phase I across this stratum makes neither financial nor technical sense until the level of change in the forest has somewhat slowed. Instead a ground-based audit and monitoring program should be initiated within the next two years to meet the following objectives:

- Obtain a more reliable estimate of current volume, stand structure (including understory) to support the development of yield curves for these stand types;
- Obtain a more reliable estimate of current volume and merchantability in mature Pl-leading stands to support emerging information needs for sawlog, chips and bio-energy investment opportunities;
- Confirm the reliability and accuracy of the MFR Satellite Mountain Pine Beetle Attack Mapping for attack level/intensity; and
- Provide feedback to guide investment decisions on a new full phase VRI program.

The monitoring program would have 10 year remeasurement periods, or as the business case requires. There is uncertainty about the structure and variability of these stand types that limits the current ability to select an appropriate plot design (this includes looking at options of establishing plot clusters). A light reconnaissance of the affected area should be completed prior to developing the sample plan to ensure the plot design captures the key information needs.

[18] To some degree "dead-Pl" is a misnomer. The VRI Phase I program has identified significant amounts of area where live-Pl still exist. The majority of this stratum, however, can be described as having high components of dead-Pl.

Following reconnaissance, this document will be amended to describe the proposed sample methods.

6.3 Target Population

The target population is all Pl leading stands greater than 47 years in the vegetated-treed landbase on the TSA.

6.4 Sample Size

The sample size chosen will be dependent on the desired sampling error and available funding.

7.0 CMI AND VRI PHASE II IMPLEMENTATION

7.1 Schedule

7.1.1 PHR Sampling Schedule

The Quesnel TSA licensees tendered the field portion of the CMI program in the summer of 2009 based on the plot design presented in this sample plan. Northview Resource Logistics won the tender and installed one-half of the CMI plots in October 2009. Nona Phillips completed the field audit. Funding permitting, the remaining plots will be installed in the 2010 field season.

7.1.2 Mature Green Sampling Schedule

Sampling will begin in the 2010 field season, immediately following the pre-work meeting. The intent is to complete sampling in the 2010 field season. Crews will be audited at the start of the project and as the auditor deems necessary throughout the project. Data will be entered into TIMVEG and non-standard data entered into a database or spreadsheet.

Upon completion of the Phase II program the NVAF tree matrix, sample size, and sample plan update will be completed. The NVAF program (destructive sampling and data entry) will be completed early in the 2011 field season. Final data compilation, inventory assessment, and reporting will be completed before December 31, 2011.

Activities	2009-2010				2011			
	Sept.- Mar	Apr.- June	July– Sep.	Oct.- Dec.	Jan.- Mar	Apr.- June	July– Sep.	Oct.- Dec.
1. Sample Planning (CMI & Phase II)								
2. Select sample locations								
3. Approve sample plan								
4. CMI Sampling								
5. CMI QA								
6. Phase II Sampling								
7. Phase II QA								
8. NVAF sample selection								
9. Approve sample plan								
10. NVAF sampling								
11. NVAF QA								
12. Compilation and analysis								
13. Complete final report								

Quesnel Licensees MFR Sampling Contractors

Figure 3. Proposed 2010 and 2011 implementation schedule.

7.2 Proposed budget

The proposed budget for all activities on the Quesnel TSA should cost approximately $300,000, including audit, quality control, helicopter costs and the compilation and analysis.

Table 9. Proposed program field activities cost.

Phase	Cost	% of Phase	% of Total
CMI			
Field Sampling	$85,500	70	29
Helicopter[b]	$10,000	8	3
Field Audit	$7,000	6	2
Quality Control and Analysis[c]	$20,000	16	7
Subtotal	*$122,500*	*100*	*42*
Phase II			
Field Sampling[a]	$75,000	60	26
Helicopter[b]	$10,000	8	3
Field Audit	$10,000	8	3
Quality Control and Analysis[c]	$30,000	24	10
Subtotal	*$125,000*	*100*	*43*
NVAF			
Field Sampling[a]	$28,000	62	9
Helicopter[b]	$5,000	11	2
Field Audit	$5,000	11	2
Quality Control and Analysis[c]	$7,000	17	2
Subtotal	*$45,000*	*100*	*15*
Total	*$292,500*		*100*

[a] Costs are based on a field crew rate of $1,500/day.
[b] Helicopter costs are estimates based on generally good road access throughout the TSA.
[c] Quality control includes technical support, and ground sampling program management, VPIP update, extra sample selection, etc.

7.3 Roles and Responsibilities

Quesnel TSA licencees

- Develop and update sample plan.
- Coordinate project activities.
- Select sample points, polygons, and locations within polygons.
- Prepare sample packages.
- Select field crews.
- Ensure audit program is implemented.
- Check data after initial compilation
- Validate and compile data.

- Provide data to MFR.
- Complete data analysis and report and submit to MFR for review.

Field Contractors

- Complete field sampling.
- Enter the standard data (including trees cores and GPS) into TIMVEG and non-standard data into a database or spreadsheet and submit to the licencees.
- Complete internal quality control and submit data to the licencees at the conclusion of field sampling.

CMI and Phase II Auditor

- Third party Phase II certified auditor will audit a minimum of 10% of the Phase II samples.

NVAF Field Contractors

- Complete destructive sampling.
- Enter the sample data and provide to the licencees.

NVAF Auditor

- NVAF-certified auditor will audit a minimum of 10% of the NVAF sample trees.

MFR

- Review and approve the sample plan.
- Review and approve the final analysis.
- Be the custodian of the VRI standard and non-standard sample and population data.
- Audit the VRI process to ensure sample plan commitments are achieved and MFR standards are met.
- Review QA reports for acceptance.

7.4 MFR Deliverables

The deliverables for the MFR upon completion of the ground sampling program include:

1. Sample plan and individual sample packages.
2. Plot cards, validated TIMVEG ground sampling field data and analysis data.
3. NVAF destructive sampling data in a digital format accepted by the MFR.
4. Corrected GPS data.
5. Individual quality assurance reports.
6. Final analysis and report, including description of data and analysis issues

APPENDIX I - QUESNEL TSA LANDBASE

The Quesnel TSA is located in the northern part of the Southern Interior Forest Region, lying in the Fraser Basin and the Interior Plateau between the Coast Mountains on the west and the Cariboo Mountains on the east. The TSA covers about 1.6 million hectares in total, of which approximately 1.3 million hectares is productive Crown forest. The timber harvesting land base comprises about hectares 1.0 million hectares. [19]

The climate, terrain and forests of the TSA are varied. West of the Fraser River, the forests are predominately lodgepole pine, while east of the Fraser River, the forests contain more spruce and balsam. Overall, the TSA is covered by stands of lodgepole pine (85 percent), spruce (10 percent), and Douglas-fir (3 percent) with hemlock and balsam, and deciduous species forming minor components.

The Biogeoclimatic Ecosystem Classification zones present are the sub-boreal pine-spruce; sub-boreal spruce; montane spruce; Engelmann spruce-subalpine fir; interior Douglas-fir; interior cedar-hemlock; and alpine tundra.

Table 10. Area distribution by BEC subzone in the Quesnel TSA.

BEC Zone, Sub-zone, Variant	Quesnel Area (ha.)	Quesnel (%)
AT	9,846.6	0.62%
AT All	**9,846.6**	**0.62%**
BG xh		
BG xw		
BG All		
CWH ds		
ESSFmv1	783.9	0.05%
ESSF mw		
ESSFwk1	65,200.0	4.07%
ESSFwc3	32,400.0	2.02%
ESSFxv	17,127.9	1.07%
ESSF All	**115,511.8**	**7.22%**
ICH mk3		
ICH wk2		
ICHwk4	21,600.0	1.35%

[19] BC Ministry of Forests. 2004. Quesnel Timber Supply Area Rationale for Allowable Annual Cut (AAC) Determination. 59p.

BEC Zone, Sub-zone, Variant	Quesnel Area (ha.)	Quesnel (%)
ICH All	**21,600.0**	**1.35%**
IDFdk3	7,118.8	0.44%
IDF dk4		
IDF dw, unv		
IDFxm	2,186.8	0.14%
IDF All	**9,305.6**	**0.58%**
MS dc		
MS dv		
MS xk		
MSxv	339,119.6	21.19%
MS All	**339,119.6**	**21.19%**
SBPSdc	263,518.1	16.47%
SBPSmc	47,715.8	2.98%
SBPSmk	173,413.4	10.84%
SBPSxc	80,448.4	5.03%
SBPS All	**565,095.7**	**35.32%**
SBSdk	536.0	0.03%
SBSdw1	110,306.2	6.89%
SBSdw2	167,209.1	10.45%
SBSmc1	9,200.0	0.57%
SBSmc2	82,237.7	5.14%
SBSmc3	14,885.5	0.93%
SBSmh	78,363.3	4.90%
SBSmw	58,800.0	3.67%
SBSwk1	18,000.0	1.12%
SBS All	**539,537.8**	**33.72%**
TSA Total	**1,600,017.1**	**100.00%**

APPENDIX II – PHR CMI SAMPLE LIST

Table 11. Quesnel TSA CMI sample list.

Plot Number	UTM Easting	UTM Northing	MAP_ID	Leading Species
446-5924	446,020	5,923,718	093G041	Conifer
446-5919	445,807	5,918,716	093G041	Pl
566-5914	565,852	5,913,592	093G040	Conifer
416-5915	415,584	5,914,987	093F039	Pl
420-5910	420,373	5,909,773	093F040	Conifer
460-5898	459,960	5,898,071	093G023	Pl
580-5888	579,784	5,887,939	093H011	Conifer
565-5884	564,564	5,883,582	093G010	Conifer
459-5883	459,322	5,883,067	093G002	Pl
484-5882	484,329	5,882,003	093G004	Pl
539-5880	539,343	5,879,653	093G008	Pl
564-5879	564,350	5,878,581	093G010	Pl
574-5878	574,352	5,878,151	093H001	Conifer
579-5878	579,354	5,877,936	093H001	Conifer
589-5878	589,356	5,877,506	093H002	Conifer
624-5876	624,369	5,875,995	093H005	Pl
504-5876	504,120	5,876,149	093G006	Pl
609-5872	609,148	5,871,642	093A094	Conifer
619-5871	619,152	5,871,210	093A094	Conifer
629-5871	629,155	5,870,778	093A095	Conifer
634-5871	634,157	5,870,561	093A095	Conifer
559-5869	558,919	5,868,793	093B100	Pl
439-5869	438,680	5,868,913	093B091	Pl
559-5864	558,704	5,863,792	093B100	Conifer
564-5864	563,705	5,863,577	093B100	Conifer
428-5864	428,466	5,864,336	093C100	Pl
438-5864	438,468	5,863,912	093B091	Pl
448-5863	**448,470**	**5,863,487**	**093B092**	**Pl**
518-5861	518,482	5,860,505	093B087	Pl
443-5859	443,257	5,858,698	093B081	Pl
463-5858	463,261	5,857,849	093B083	Pl
478-5857	478,263	5,857,211	093B084	Pl
488-5857	488,264	5,856,786	093B085	Pl
493-5857	493,265	5,856,572	093B085	Pl
508-5856	508,267	5,855,932	093B086	Pl
523-5855	523,269	5,855,290	093B087	Pl
528-5855	528,270	5,855,077	093B088	Decid
543-5854	543,272	5,854,434	093B089	Decid
433-5854	433,043	5,854,122	093B081	Pl
438-5854	438,044	5,853,910	093B081	Pl
483-5852	483,051	5,851,998	093B084	Pl
553-5849	553,059	5,849,004	093B079	Pl
423-5850	422,829	5,849,544	093C080	Pl

448-5848	447,834	5,848,485	093B072	Pl

Bolded is a BC-NFI plot that has already been established.

Plot number	UTM Easting	UTM Northing	MAP_ID	Leading Species
563-5844	562,845	5,843,574	093B080	Decid
423-5845	422,617	5,844,543	093C080	Pl
438-5844	437,620	5,843,908	093B071	Pl
583-5838	582,633	5,837,712	093A062	Pl
482-5837	482,412	5,836,996	093B064	Pl
547-5834	547,415	5,834,218	093B069	Pl
497-5826	496,986	5,826,357	093B055	Pl
502-5826	501,986	5,826,143	093B056	Pl
522-5825	521,985	5,825,288	093B057	Pl
547-5824	546,986	5,824,217	093B059	Pl
477-5822	476,774	5,822,208	093B054	Pl
522-5820	521,771	5,820,288	093B057	Conifer
542-5819	541,772	5,819,431	093B059	Pl
487-5817	486,560	5,816,783	093B055	Pl
517-5816	516,558	5,815,502	093B047	Decid
522-5815	521,557	5,815,288	093B047	Pl
521-5805	521,130	5,805,289	093B037	Decid

APPENDIX III – GREEN MATURE SAMPLE LIST

Table 12. Mature Green Sample List.

Plot No	NVAF	Stratum	Sub Stratum	Mapsheet	Polygon	Area (ha)	Ht (m)	Age (yrs)	Vol (m3/ha)	SPH	BA (m2/ha)	Lor. Ht. (m)	SI (m)	UTM Zone	UTM North	UTM East
1		1	1	093B047	708	36.2	24.7	104	107	308	13.4	24.2	16.0	10	5807499	523432
2		1	1	093B057	670	22.3	19.3	112	154	668	31.4	16.5	11.0	10	5821200	514602
3	Y	1	1	093B077	301	57.9	30.4	105	396	778	48.4	25.4	20.6	10	5844872	525633
4		1	1	093B078	727	43.6	18.1	58	135	856	26.9	16.9	19.7	10	5849793	530052
5		1	1	093B100	405	114.7	21.6	83	267	946	46.7	19.1	16.7	10	5861858	557122
6		1	2	093B048	548	17.5	19.3	113	122	790	25.5	16.7	12.5	10	5814118	534935
7	Y	1	2	093B048	715	155.3	25.5	114	93	224	12.8	23.8	16.4	10	5815734	532300
8		1	2	093B059	122	87.9	18.8	74	136	1,811	34.5	15.1	15.9	10	5818469	540932
9		1	2	093B099	448	40.5	37.8	106	668	420	72.0	32.4	25.2	10	5867687	545047
10		1	2	093G007	903	18.5	20.7	84	145	984	31.2	17.2	16.0	10	5880115	523935
11	Y	1	2	093G018	6	3.6	19.3	54	119	1356	32.9	14.8	20.4	10	5883554	530195
12		1	2	093G026	41	12.6	21.6	73	157	739	25.9	18.9	18.4	10	5895179	506742
13		1	3	093A061	242	5.9	25.3	119	100	209	16.4	24.3	16.7	10	5838635	568248
14		1	3	093A071	135	67.8	26.3	108	41	118	6.4	26.0	18.3	10	5840095	576226
15	Y	1	3	093B089	321	14.6	18.6	63	75	847	16.3	18.0	16.6	10	5853239	547834
16		1	3	093B097	244	26.4	27.4	104	206	574	35.9	24.7	19.6	10	5863795	518928
17		1	3	093B098	267	9.6	21.5	94	94	410	20.7	18.5	15.4	10	5863500	532843
18	Y	1	3	093G007	1167	12.9	22.7	69	239	1,244	42.0	20.6	19.6	10	5883393	517562
19		1	3	093G017	508	50.1	25.4	99	272	957	40.7	23.1	18.4	10	5888540	514375
20		1	3	093G018	452	26.6	22.4	83	203	1,136	31.0	22.5	17.4	10	5888281	529796
21		2	1	093A071	176	17.7	33.3	133	207	171	22.2	30.6	19.9	10	5841217	575773
22	Y	2	1	093A092	51	63.0	23.1	233	235	998	40.0	18.0	6.2	10	5867184	591722
23		2	1	093A094	105	109.5	18.2	203	109	501	25.0	14.8	5.6	10	5864176	608027
24		2	1	093A094	156	11.3	32.1	263	407	648	50.0	26.8	10.9	10	5866568	619955

Plot No	NVAF	Stratum	Sub Stratum	Mapsheet	Polygon	Area (ha)	Ht (m)	Age (yrs)	Vol (m3/ha)	SPH	BA (m2/ha)	Lor. Ht. (m)	SI (m)	UTM Zone	UTM North	UTM East
25		2	1	093A095	471	28.2	25.2	233	319	824	50.0	20.6	8.6	10	5866262	633973
26	Y	2	1	093A095	413	36.6	28.3	183	196	261	30.0	24.0	11.6	10	5872695	633550
27		2	1	093B067	26	63.6	24.4	123	197	343	30.3	20.7	13.5	10	5828193	517406
28		2	1	093B067	524	42.6	32.6	149	79	70	8.0	30.0	17.8	10	5835311	519614
29		2	1	093B080	858	12.6	32.4	144	94	70	10.1	29.9	18.1	10	5848674	565473
30	Y	2	1	093G010	528	70.2	18.3	153	190	1,335	40.3	15.6	7.7	10	5883045	565447
31		2	1	093G020	20	21.8	23.3	179	280	1,096	44.7	18.6	8.6	10	5884403	566507
32		2	1	093H001	156	34.3	30.1	223	246	220	30.0	26.7	11.0	10	5878475	573869
33		2	1	093H002	127	50.4	30.3	174	81	81	10.0	26.2	13.9	10	5874748	583629
34	Y	2	1	093H002	110	16.0	23.4	144	301	1,077	50.3	19.0	11.7	10	5875242	590766
35		2	1	093H002	346	29.7	33.3	199	542	772	55.9	28.1	15.0	10	5879461	581227
36		2	1	093H011	102	34.9	24.2	173	243	675	39.9	19.7	10.5	10	5885527	579984
37		2	1	093H011	439	43.5	20.2	178	116	452	20.0	18.3	7.6	10	5890808	573697
38	Y	2	1	093H011	671	82.4	23.4	174	58	130	9.9	19.7	8.8	10	5890441	577590
39		2	1	093H011	536	133.6	18.2	173	170	477	29.8	18.9	6.7	10	5891840	575345
40		2	1	093H031	71	48.1	23.2	188	269	875	44.9	18.9	9.0	10	5914401	570400
41	Y	2	2	093B037	72	5.3	32.1	233	83	94	12.0	24.5	15.4	10	5803225	522648
42		2	2	093B058	609	33.4	29.3	184	102	198	14.0	24.0	15.1	10	5819015	530537
43		2	2	093B067	519	85.3	25.3	133	70	110	10.2	22.9	15.0	10	5834364	520675
44		2	2	093B090	1002	136.9	34.3	122	531	537	53.3	30.8	21.3	10	5858517	562590
45	Y	2	2	093G007	916	17.0	28.4	134	325	891	45.5	23.3	16.8	10	5880455	513628
46		2	2	093G007	988	12.5	34.4	133	631	638	70.4	29.9	20.5	10	5881525	514376
47		2	2	093G026	58	28.0	35.3	163	674	621	74.8	30.3	19.3	10	5895223	512756
48		2	2	093G026	514	27.6	34.3	163	481	642	59.8	28.1	18.7	10	5897041	507723
49	Y	2	3	093B099	72	12.0	25.3	124	140	312	25.2	23.1	16.4	10	5861790	551708
50		2	3	093G026	414	127.5	30.2	123	321	678	45.3	27.4	20.6	10	5902350	505445

APPENDIX IV – MATURE GREEN TARGET AND SAMPLE COMPARISONS

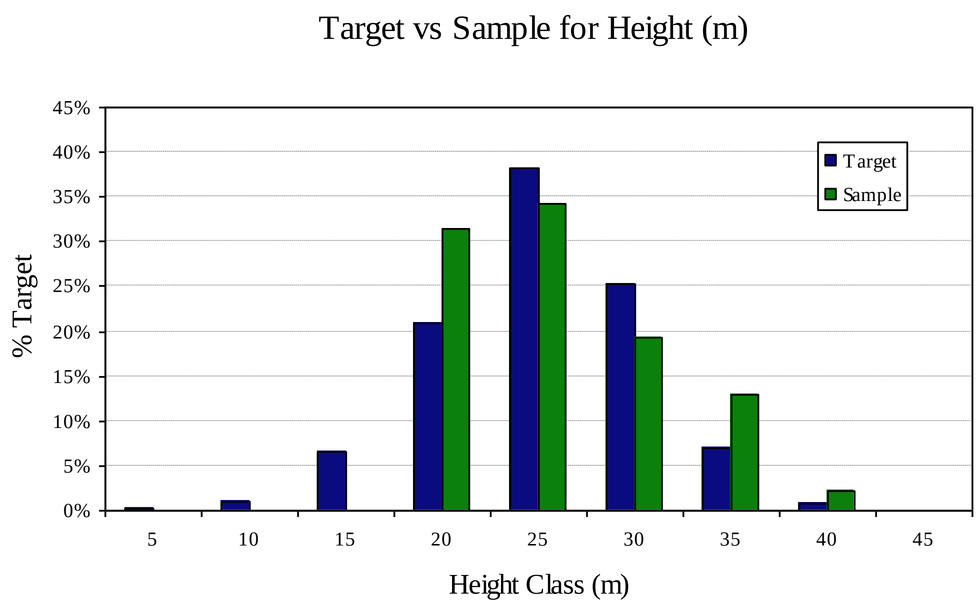

Figure 4. Quesnel TSA Mature Green Target vs. Sample for Height (m).

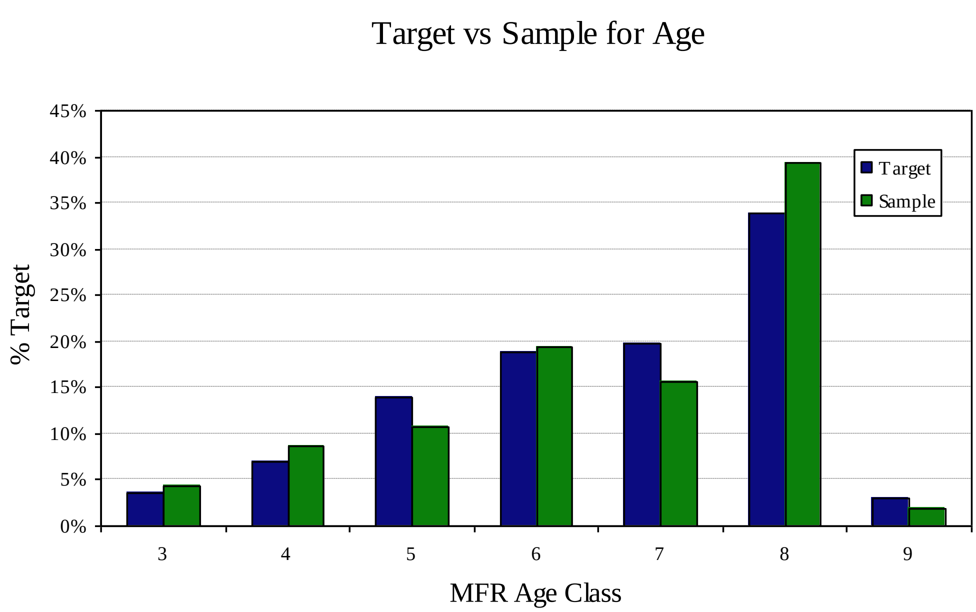

Figure 5. Quesnel TSA Mature Green Target vs. Sample for Age.

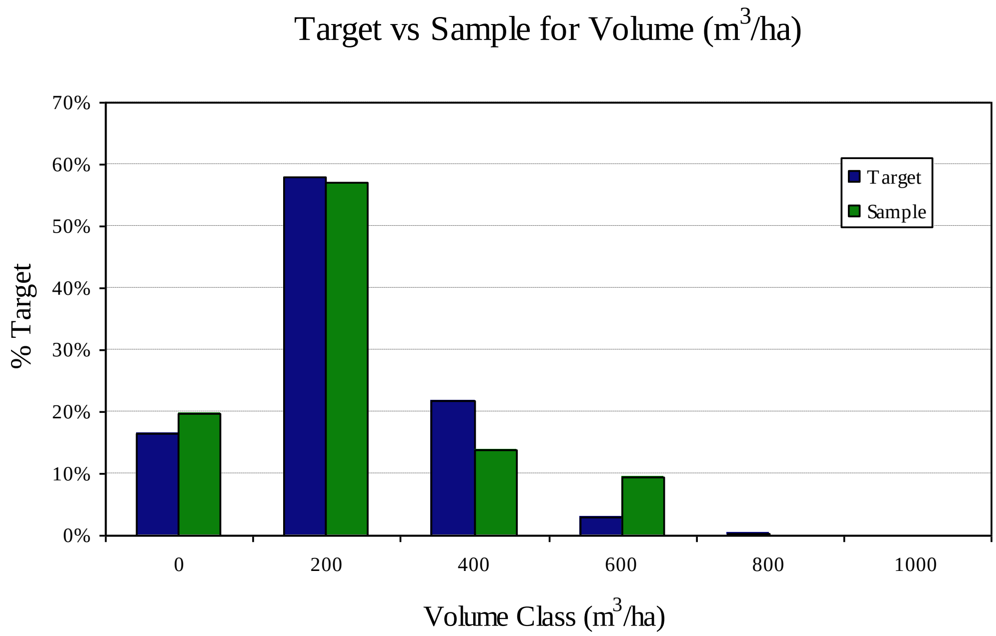

Figure 6. Quesnel TSA Mature Green Target vs. Sample for Volume (m^3/ha).

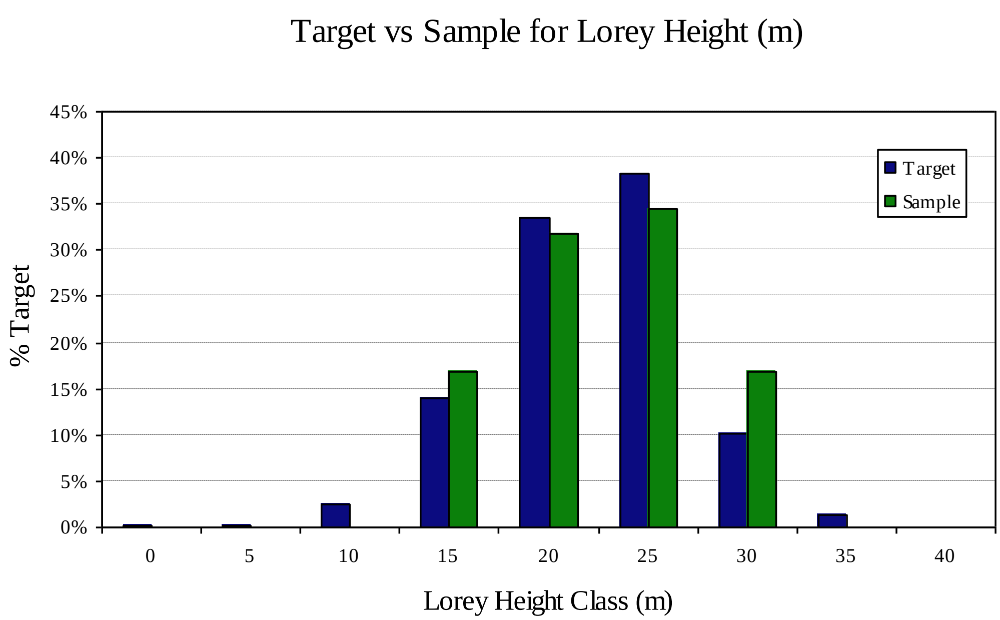

Figure 7. Quesnel TSA Mature Green Target vs. Sample for Lorey Height (m).

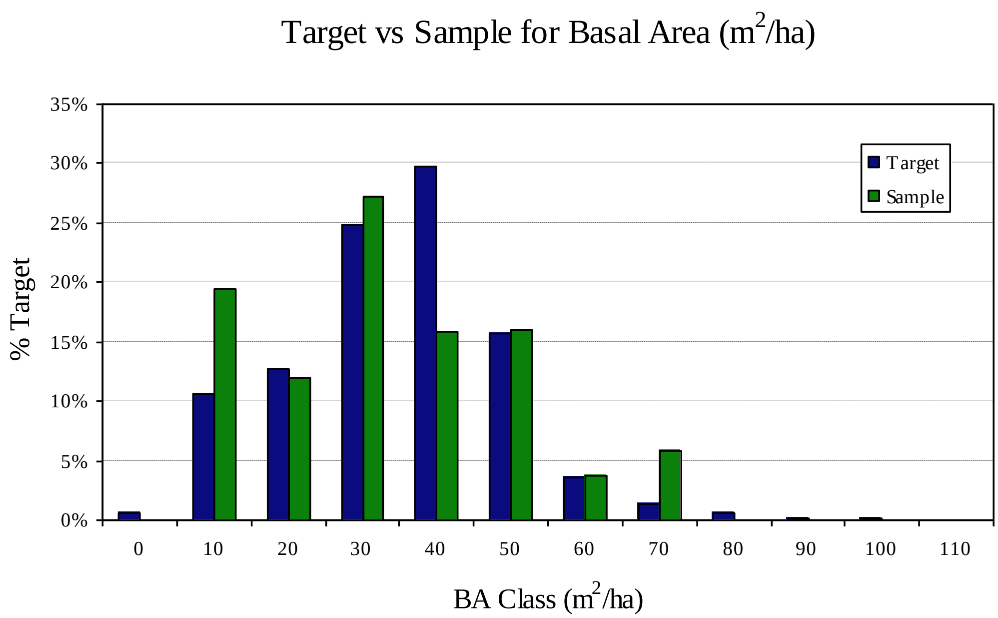

Figure 8. Quesnel TSA Mature Green Target vs. Sample for Basal Area (m^2/ha).

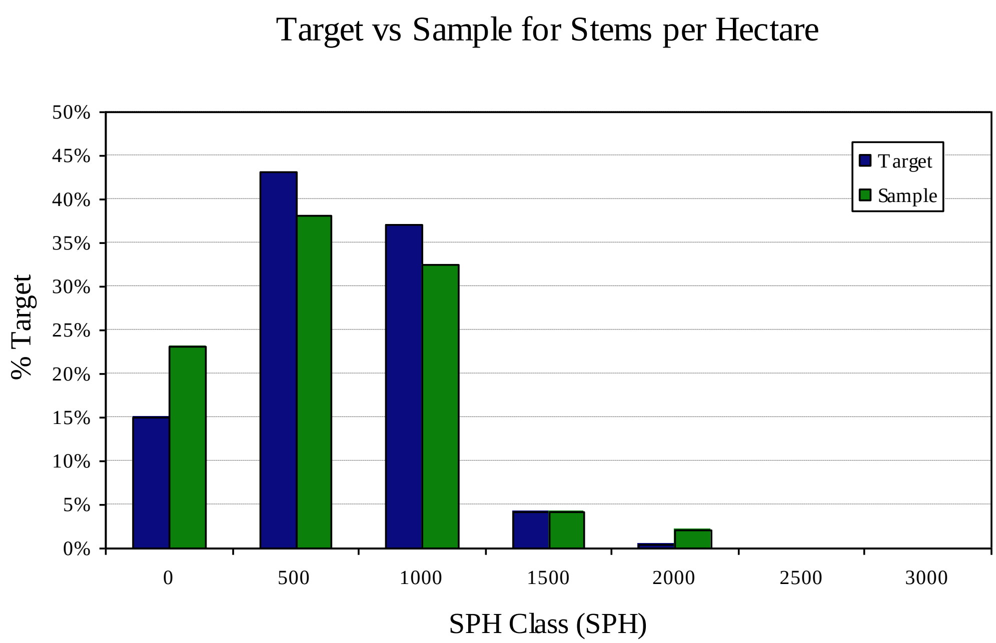

Figure 9. Quesnel TSA Mature Green Target vs. Sample for SPH.

APPENDIX V – MATURE GREEN SAMPLE DISTRIBUTION

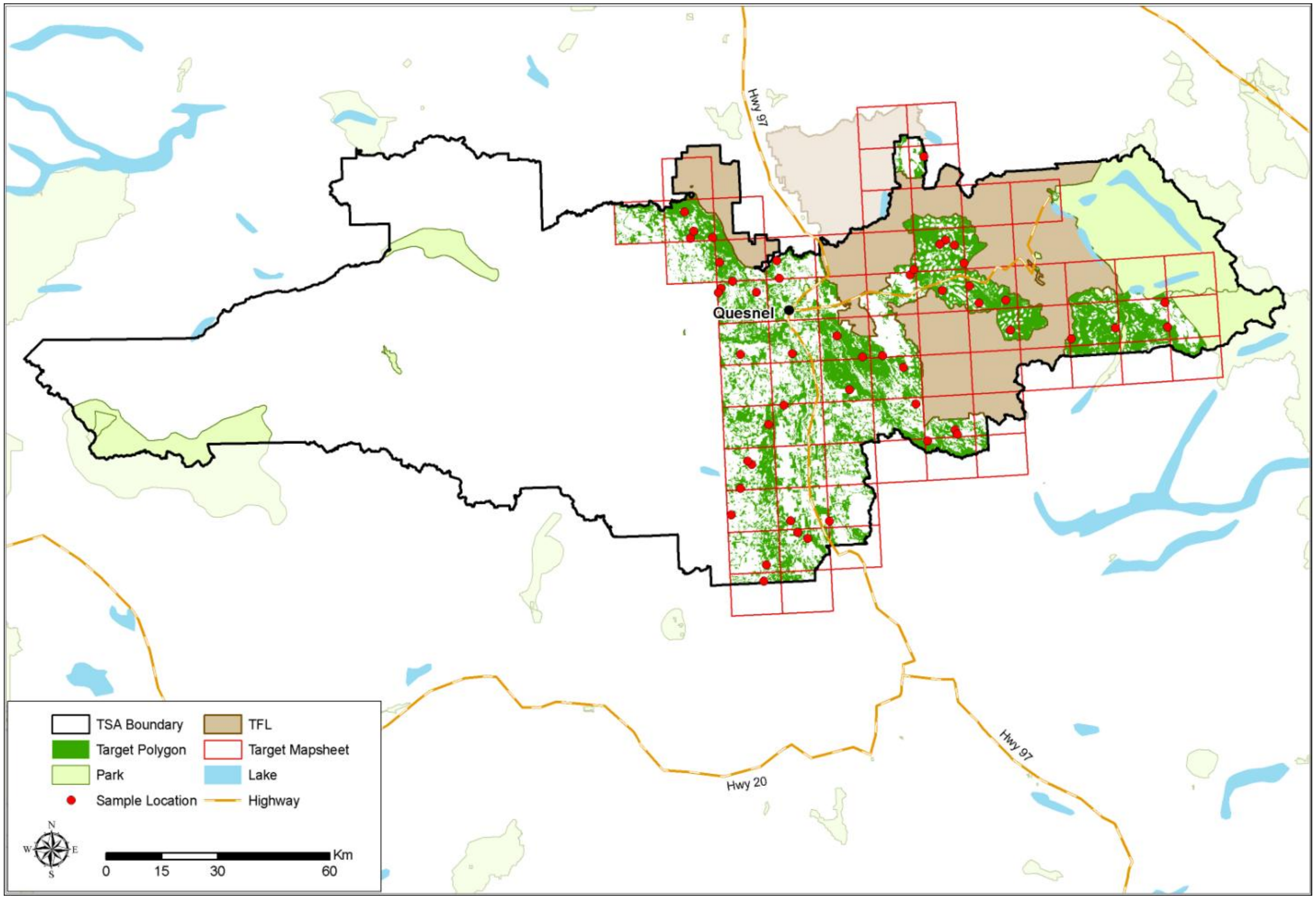

Figure 10. Quesnel TSA Phase II Sample Distribution.