INVENTORY ANALYSIS OF THE MACKENZIE TSA

Prepared for:

Ministry of Forests, Lands and Natural Resource Operations
Forest Analysis and Inventory Branch
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Ministry of Forests, Lands and Natural Resource Operations
Forest Analysis and Inventory Branch
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Attention: Graham Hawkins

Subject: Inventory Analysis of Mackenzie TSA

Mr. Hawkins:

Please find enclosed the final report for the Inventory Analysis of the Mackenzie TSA as well as the accompanying spreadsheet (mack_plot_data_07dec2012.xlsx) containing the associated data tables.

Please do not hesitate to call if you have any questions on the report or associated work.

Yours Truly,

[ORIGINAL SIGNED]

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EXECUTIVE SUMMARY

The Vegetation Resources Inventory Strategic Inventory Plan (VSIP) for the Mackenzie Timber Supply Area (TSA) was completed in 2005 (Nona Phillips Forestry Consulting) at which time the Phase I program had been completed for approximately 185 mapsheets across the TSA. The VSIP recommends the completion of the remaining mapsheets as well as the installation of 140 VRI Phase II timber emphasis plots and destructive sampling of 170 net volume adjustment factor (NVAF) trees.

According to the *Mackenzie Timber Supply Area Vegetation Resources Inventory Project Implementation Plan for Ground Sampling and Net Volume Adjustment Factor Sampling* (Nona Phillips Forestry Consulting, 2011a) (the Phase II VPIP), the Phase I VRI program for the TSA was two-thirds completed in 2012 with the northern third remaining. The VPIP recommends the installation of 70 Phase II plots with 50 plots in the mature land base and 20 plots in the immature land base. A sampling error target of +/-15% (95% probability) is established for net volume in the mature land base. There is no sampling error target on the immature land base.

Table i below shows that the overall average net merchantable volume on the mature land base is overestimated by approximately 14% (+/- 28.7% @ 95% probability). However, comparing only live volumes shows that volume is underestimated by almost 7% (+/- 28.2% @ 95% probability) (Table ii). Comparing live + dead volumes shows that volumes are underestimated by over 21% (+/- 23.9% @ 95% probability).

An assessment of model and attribute-related bias shows that overall, model-related bias underestimates volumes by approximately 3% (4.0 m^3/ha) while the attribute-related bias overestimates volumes by approximately 12% (17.4 m^3/ha) resulting in an overall volume bias of approximately 9% (13.4 m^3/ha). It is important to note that stratum-level biases are considerably higher than the overall averages with extremely high and low values cancelling each other out.

Considerable dead volume was measured in the Phase II samples such that its inclusion in the analysis as the potential to completely changes the overall result. With an additional 51 m^3/ha of dead volume in the Phase II mature samples (48 m^3/ha overall), the overall mature volume ratio changes from 0.86 to 1.21 – a 35% increase in volume.

Overall, across the entire land base, approximately 16% of the net merchantable Phase I volume is considered to be dead. The Phase II data shows that approximately 29% of the net merchantable volume is dead. Given this discrepancy the results in Table ii show that a large component of the Phase I volume overestimation is attributable to volume that is classified as live in the Phase I and dead in the Phase II. This is especially true in SX-Mature stratum where the dead volume is underestimated by approximately 19% (35 m^3/ha). Consistent with other units, the dead volume estimates in the pine stratum are much closer to the actual dead volume percentages.

Table i: Analysis Attribute Summary – VDYP Volume

	BL-Mature	DECID-Mature[1]	PL-Mature	SX-Mature	Overall-Mature	Non-THLB	THLB	Immature
N	21	2	13	14	**50**	36	14	20
Total Area	1,443,981	138,430	860,769	907,872	**3,351,052**			246,880
Age (years)								
n	19	2	13	13	**47**	34	13	17
Phase II Ground	161.5	60.4	136.2	162.9	**141.4**	157.2	133.3	31.8
Phase I Inventory	167.5	73.5	149.8	167.2	**148.9**	165.0	141.5	32.1
Ratio	0.9643	0.8211	0.9092	0.9748	**0.9501**	0.9528	0.9421	0.9887
Sampling Error	16.5%	36.3%	15.5%	23.3%	**10.5%**	13.3%	13.5%	15.5%
Height (m)								
n	19	2	13	13	**47**	34	13	17
Phase II Ground	16.2	15.3	21.3	20.0	**17.4**	17.2	22.4	11.3
Phase I Inventory	14.0	15.1	23.4	20.2	**17.2**	16.2	24.1	8.3
Ratio	1.1569	1.0113	0.9068	0.9914	**1.0150**	1.0610	0.9292	1.3593
Sampling Error	11.9%	77.1%	15.1%	15.0%	**8.3%**	9.5%	15.8%	20.8%
Basal Area (m2/ha) @7.5 cm+ dbh								
n	21	2	13	14	**50**	36	14	20
Phase II Ground	25.4	10.5	26.7	26.3	**25.3**	26.3	22.9	14.1
Phase I Inventory	17.8	19.1	31.2	30.8	**24.8**	20.7	36.0	11.6
Ratio	1.4272	0.5487	0.8569	0.8524	**1.0216**	1.2738	0.6365	1.2189
Sampling Error	29.1%	222.2%	33.3%	35.2%	**19.8%**	22.1%	33.8%	45.3%
Trees / ha @ 7.5cm+ dbh								
n	21	2	13	14	**50**	36	14	20
Phase II Ground	1,210	602	1,119	1,051	**1,118.2**	1,186	941	1,287
Phase I Inventory	853	803	812	763	**816.1**	823	796	2,124
Ratio	1.4184	0.7496	1.3780	1.3761	**1.3702**	1.4414	1.1821	0.6061
Sampling Error	31.4%	108.2%	43.7%	33.7%	**20.3%**	21.1%	51.9%	64.8%
Volume / ha (m3/ha) @ 12.5 cm+ dbh (net dbw)								
n	21	2	13	14	**50**	36	14	20
Phase II Ground	114.7	39.2	139.6	137.1	**124.0**	126.6	118.8	26.7
Phase I Inventory	68.2	128.0	230.2	186.7	**144.4**	98.3	268.4	15.7
Ratio	1.6807	0.3063	0.6064	0.7345	**0.8590**	1.2886	0.4425	1.7037
Sampling Error	40.2%	181.1%	46.7%	44.4%	**28.7%**	32.5%	39.2%	70.5%
Lorey Height (m)								
n	18	1	13	14	**46**	32	14	11
Phase II Ground	13.8	11.1	17.3	17.1	**14.4**	15.1	17.1	10.8
Phase I Inventory	12.9	23.7	19.7	17.7	**15.1**	14.5	21.1	10.0
Ratio	1.0663	0.4689	0.8754	0.9651	**0.9509**	1.0419	0.8066	1.0781
Sampling Error	13.9%	0.0%	16.8%	16.5%	**8.9%**	10.8%	16.0%	16.3%
Site Index (m)								
n	17	1	9	11	**37**	28	9	12
Phase II Ground	7.9	8.8	11.9	9.2	**9.3**	8.3	12.4	20.7
Phase I Inventory	5.4	10.1	10.9	8.5	**7.9**	6.5	11.5	15.9
Ratio	1.4481	0.8782	1.0923	1.0803	**1.1834**	1.2795	1.0781	1.3021
Sampling Error	21.4%	0.0%	23.7%	24.5%	**13.9%**	16.3%	28.9%	12.8%

[1] Given that this stratum only has two samples and very high sampling error the reader should exercise caution in drawing any conclusions from this information.

Table ii: Volume Analysis Summary – MPB Volume

	BL-Mature	DECID-Mature[2]	PL-Mature	SX-Mature	Overall-Mature	Non-THLB	THLB	Immature
N	21	2	13	14	**50**	36	14	20
Total Area	1,443,981	138,430	860,769	907,872	**3,351,052**			246,880
Live MPB Volume / ha (m3/ha) @ 12.5 cm+ dbh (net dbw)								
n	21	2	13	14	50	36	14	20
Phase II Ground	114.7	39.2	139.6	137.1	124.0	126.6	118.8	26.7
Phase I Inventory	64.5	85.4	149.8	170.9	116.1	92.6	180.8	14.9
Ratio	1.7770	0.4590	0.9319	0.8025	1.0683	1.3672	0.6568	1.7856
Sampling Error	41.7%	181.1%	44.5%	41.9%	28.2%	32.7%	39.8%	71.8%
Live + Dead MPB Volume / ha (m3/ha) @ 12.5 cm+ dbh (net dbw)								
n	21	2	13	14	50	36	14	20
Phase II Ground	143.4	64.7	234.2	187.1	175.3	159.2	219.6	31.7
Phase I Inventory	68.2	128.0	230.2	186.7	144.4	98.3	268.4	15.7
Ratio	2.1018	0.5060	1.0173	1.0024	1.2141	1.6199	0.8183	2.0239
Sampling Error	35.9%	126.4%	30.6%	34.7%	23.9%	29.2%	25.0%	72.0%

The following summary of recommendations is provided based on our experience with this and other inventory analysis projects around the Province:

- As funding permits, consider revisiting existing Phase II plot locations to update dead volume estimates in light of the recent expansion of the MPB infestation;
- Given the uncertainty of volume estimates inside and outside the THLB, consider testing the sensitivity of the size of the THLB using an adjusted inventory.
- Given the difficulty in photo-interpreting basal area and the heavy reliance of VDYP 7 on basal area for generating volume estimates, investigate modifications to inventory procedures to improve the accuracy of this attribute;
- Develop a province-wide analysis data set comprised of all the Phase II plots in the Ministry's data warehouse, linked to the corresponding Phase I polygon. This data set will then be used to assess Phase I volume bias and identify trends in model and attribute bias. Identifying consistent trends in attribute bias, whether tied to specific geographies, specific forest types, or even specific classifiers, inventory procedures can be focussed in areas that have the greatest likelihood of reducing volume errors and improving the overall accuracy of the inventory.
- Focus the target population and stratification with the goal of minimizing uncertainty in the short-term (50 years) timber harvesting land base by excluding areas from the target population where timber harvesting is not legally authorized, is unlikely in the next 50 year or where VDYP cannot reasonably project volumes.
- Establish a minimum number of plots for each stratum and enforce this as part of each Phase II VPIP.

[2] Given that this stratum only has two samples and very high sampling error the reader should exercise caution in drawing any conclusions from this information.

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1 INTRODUCTION

1.1 Background

The Vegetation Resources Inventory Strategic Inventory Plan (VSIP) for the Mackenzie Timber Supply Area (TSA) was completed in 2005 (Nona Phillips Forestry Consulting). The VSIP outlines the inventory activities and products required to address the forest management issues identified by stakeholders and provides general strategic direction for implementing the Vegetation Resources Inventory (VRI) program across the TSA. When the 2005 VSIP was completed, the Phase I program had been completed for approximately 185 mapsheets across the TSA. The 2005 VSIP recommends the completion of the remaining mapsheets as well as the installation of 140 VRI Phase II timber emphasis plots and destructive sampling of 170 net volume adjustment factor (NVAF) trees.

According to the *Mackenzie Timber Supply Area Vegetation Resources Inventory Project Implementation Plan for Ground Sampling and Net Volume Adjustment Factor Sampling* (Nona Phillips Forestry Consulting, 2011a) (the Phase II VPIP), the Phase I VRI program for the TSA was two-thirds completed in 2012 with the northern third remaining. The VPIP recommends the installation of 70 Phase II plots with 50 plots to be installed in the mature land base and 20 plots in the immature land base. The sampling error target of +/-15% (95% probability) on net volume in the mature land base is set. There is no sampling error target on the immature land base.

The Mackenzie TSA has been impacted by mountain pine beetle (MPB). The Ministry of Forests, Land and Natural Resource Operations (MFLNRO) has developed a process to estimate the amount of dead pine volume that exists in land bases affected by MPB. Through the use of satellite detection of MPB damage and an algorithm[3] developed by the MFLNO, Phase I inventory volumes in the Mackenzie TSA have been split into a live and dead component that is attached to the inventory file. It should be noted that this adjustment is only intended to reflected the dead pine component of the inventory and these adjustments are only applied to volume – the other inventory attributes are not adjusted.

1.2 Description of the TSA

As shown in Figure 1 below, the Mackenzie TSA is located in the northern portion of the province with the District of Mackenzie located in the southern portion of the TSA. According to the last Timber Supply Review (TSR) Analysis Report (MoF, 2001) the TSA is the fourth largest in the province covering approximately 6.41 million ha.

The TSA contains five biogeoclimatic zones: Alpine Tundra (AT), Boreal White and Black Spruce (BWBS), Englemann Spruce-Subalpine Fir (ESSF), Spruce-Willow-Birch (SWB) and Sub-Boreal Spruce (SBS). Stands in the TSA are predominantly pine and spruce-leading and have seen significant mountain pine beetle activity in recent years.

[3] http://www.for.gov.bc.ca/hts/vridata/standards/issues/MPB_impact_projection_2009(backgrounder).pdf

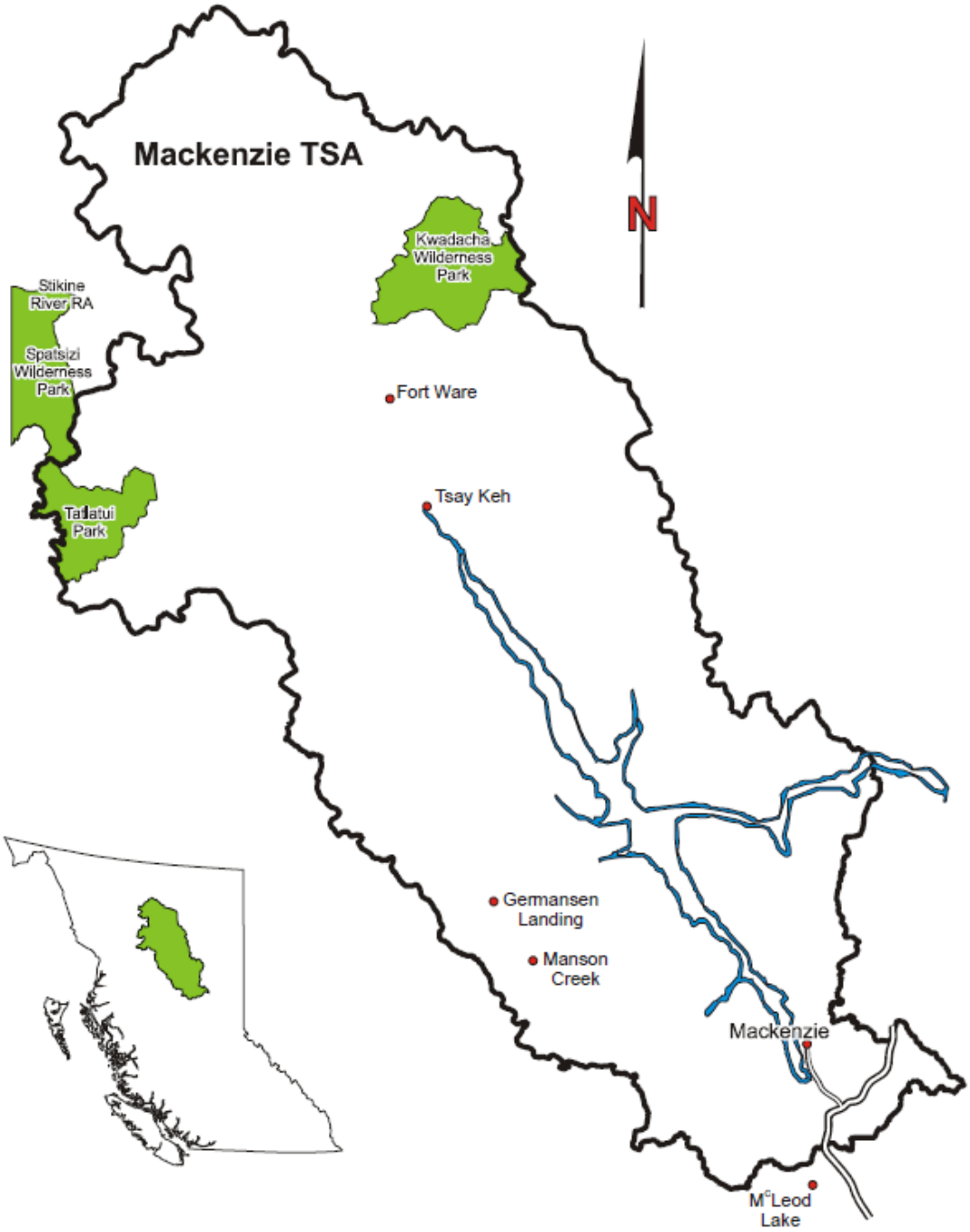

Figure 1: Map of the Mackenzie TSA[4]

[4] Extracted from http://www.for.gov.bc.ca/hts/tsa/tsa16/tsr2/analysis.pdf

1.3 Scope and Objectives

The objective of this project is to provide a statistical analysis of inventory attributes in the Mackenzie TSA as described in the MFNRO's *VRI Sample Data Analysis Procedures and Standards (Version 1-June 2011)* (the procedures).

The analysis also includes a comparison of VRI Phase I dead volume estimates with Phase II ground-measured dead volume.

Model and attribute-related bias was assessed according to the procedures included in the contract package (*Appendix B – Quantifying Ground Model Attribute Error*).

The analysis was undertaken using 70 Phase II plots and Phase I VRI data provided by the MFLNRO.

An analysis of site index (SI) was performed based on supplementary SI data and standards and procedures provided by the MFLNRO as described in Appendix VI.

2 METHODS

2.1 VRI Statistical Analysis

Vegetation Resources Inventory statistical analysis is undertaken in order to quantify the accuracy of existing Phase I photo interpreted attributes and to provide an understanding of the potential bias associated with the Phase I VRI. By understanding the accuracy of the VRI we can begin to assess the degree of risk associated with incorporating this information into important decision making processes such as timber supply review (TSR).

As described in the procedures, and outlined below, there are six main steps in the VRI analysis process:

1. **Phase II Overlay:** Phase II plot locations are overlain with Phase I VRI polygons such that each plot is tied to the Phase I VRI polygon that was sampled.

2. **Data Screening:** Plot and polygon data are compared to identify any potential overlay or UTM data entry errors. Mapsheet IDs and where possible polygon IDs are compared to identify any potentially mismatched plots. Large discrepancies between polygon and plot data are reviewed to identify any potential errors. Exceptionally large, small or missing values are identified and reviewed to identify any potential errors that may either be corrected or result in the plot being dropped from the analysis.

3. **Project Phase II Data to Year of Ground Sampling:** Phase I VRI data is projected, using the Variable Density Yield Prediction (VDYP) model version 7, to the year in which the majority of ground sampling took place. In this case Phase I data was projected to 2011.

4. **Age – Height Matching:** Age and height matching rules described in the procedures are applied to determine whether Phase II ages and heights are matched to either Phase I species 1 or species 2 ages and heights or dropped from the age-height analysis.

5. **Stratification:** Stratification rules are applied to the Phase I target population as well as to the Phase II plots. Stratum weights are calculated based on the relationship between the number of plots in each stratum and the area occupied by that stratum in the target population.

6. **Ratio of Means (ROM) and Sampling Error Calculation:** ROM and sampling errors are calculated for each stratum and for the land base as a whole according to the procedures and the included MS Excel macro. These statistics provide a direct comparison between the ground measurements and the photo interpreted values for a particular attribute. This phase of the project also includes a secondary data screening process in which potential outliers are identified and further assessed. The following seven attributes were included in this analysis:

    i) Species 1 age,

ii) Species 1 height,
iii) Basal area @ 7.5cm+ dbh utilization,
iv) Trees per hectare @ 7.5cm+ dbh utilization,
v) Lorey height @ 7.5cm+ dbh utilization,
vi) Net Merchantable Volume (net top, stump, decay, waste and breakage) @ 12.5cm+ dbh utilization, and
vii) Site Index.

2.2 Target Population

As specified in the Phase II VPIP, the target population for this project is defined as the vegetated-treed (VT) land base 15 years and older in 2011. The B.C Land Classification System Level 1 and 2 (bclcs_level_1 and bclcs_level_2) was used to define the VT land base.

As shown in Table 1, the target population represents approximately 3.6 million ha across the TSA. This information, along with the Phase I VRI area figures shown in Table 2 are taken directly from the Phase II VPIP document. There is a difference between the total population in Table 1 and the total area in Table 2 of approximately 45,000 ha. It is assumed that this area represents VT stands less than 15 years of age.

Table 1: Land Classification Summary

Land Classification	Area (ha)	% of TSA
Gross Area on File	**6,410,665**	**100%**
Indian Reserve	356	0%
Parks	897,029	14%
Private Land	8,593	0%
Net Land Base	**5,504,687**	**86%**
Non-Vegetated	720,950	11%
Vegetated-Non-Treed	1,141,025	18%
Target Population	**3,642,712**	**57%**

2.3 Phase II Sample Selection Pre-Stratification and Weights

The stratification described in the Phase II VPIP was used in this analysis and is described in Table 2.

Table 2: Stratification

Strata	N	Leading Species	Age Criteria (yrs)	Phase I VRI Area (ha)	Percent of Area (%)
BL-Mature	21	B, BL	>50	1,443,976	40%
SX-Mature	14	S, SW, SX		907,868	25%
PL-Mature	13	PLI, P, PL		860,775	24%
DECID-Mature	2	Deciduous & Other		138,430	4%
Immature	20	All	>= 15 & <= 50	246,888	7%
Total Vegetated-Treed (VT) Area				**3,597,937**	

An alternative stratification was explored using the criteria from current timber harvesting land base (THLB) definition as documented in the Mackenzie TSA Timber Supply Review Data Package (MFNRO, 2012). A list of plots falling within the current THLB was provided by the MFNRO. Samples within the current THLB were grouped and ratios and sampling error information calculated. This information is reported in Table 4. Upon review of this stratification it was determined that there are insufficient sample numbers within the THLB to further stratify beyond the THLB / Non-THLB groupings and therefore the original stratification was used in the analysis.

The stratum weighting in Table 3 shows that the BL-Mature stratum occupies approximately 40% of the target population but contains 30% of the plots. The DECID-Mature stratum occupies only 3% of the land base and therefore has only received two plots. Given the low plot count in this stratum the results may be unreliable and do not provide overly useful information. In the future, strata with low plot counts should be identified in the VPIP phase and either have additional plots added, be combined with another stratum or removed from the target population. Installing two plots in a stratum provides very little useful information about that stratum, regardless of its size.

This approach seems to have been followed for the Immature stratum where 20 plots were installed (29%) even though this area only represents 7% of the target population.

Aside from the Immature stratum, all other strata have roughly equivalent per plot area factors as shown in Table 3.

Table 3: Stratum Weighting

Stratum	Number of Plots	% of Plots	Land Base Area (ha)	% of Land Base	Area / Plot
BL-Mature	21	30%	1,443,976	40%	68,761
SX-Mature	14	20%	907,868	25%	64,848
PL-Mature	13	19%	860,775	24%	66,213
DECID-Mature	2	3%	138,430	4%	69,215
Immature	20	29%	246,888	7%	12,344
	70		**3,597,937**		

2.4 Data Sources

2.4.1 Phase I VRI

The Phase I VRI data was provided by the MFLNRO in both file geodatabase and comma-separated value (CSV) format on July 4th, 2012. The Phase I data had been projected to 2011.

The MFLNRO maintains a separate aspatial version of the VRI that contains the interpreted attributes required as inputs to VDYP. This file was also provided on July 4th, 2012.

2.4.2 Phase II Data

Compiled Phase II data was provided by the MFLNRO on June 28th, 2012. Plot data was reviewed for any obvious errors. Several plots were identified as having no age, height, basal area, stems per hectare or volume information. These plots were reviewed by the MFLNRO staff and confirmed to be valid samples.

Site index analysis was conducted using a *trees_h* file was provided by the MFLNRO along with new procedures for analyzing site index described in Appendix VI. This file contains site index measurements for individual trees. Several records did not have site index data and were checked by MFLFNRO staff and confirmed to be valid samples without site index. These trees were not included in the site index analysis.

3 RESULTS AND DISCUSSION

3.1 VRI Statistical Analysis

The results of the inventory analysis are summarized in Table 4. For each of the seven attributes examined, for each stratum, the table shows the number of included values (n), the mean of the Phase II ground and Phase I inventory values, the ratio of means and the sampling error for that attribute. As described above, the inventory update for MPB only adjusts volume and does not adjust the other attributes used by VDYP to generate volume estimates. Consequently, once the volumes are projected to the date of ground sampling using VDYP, these live / dead estimates are lost. The Phase I volumes in Table 4 reflect the volume from VDYP and provide a direct comparison between the inventory attributes and the resulting VDYP volume and the corresponding Phase II live information.

With the large component of dead volume captured in the Phase II data for this land base, the direct comparison between Phase I inventory attributes and the Phase II live information becomes less meaningful. Table 5 incorporates the live and dead volume information from the Phase I inventory and compares live volume and live + dead volume between the Phase I and Phase II. By comparing live volume to live volume and live + dead to live +dead, the volumes in Table 5 provide a better representation of the current volume in the TSA but are a function of the MPB volume projections as opposed the bias associated with the photo-interpreted inventory.

An overall summary of the mature land base shows that on average net merchantable volume is overestimated in the Phase I VRI by approximately 14% (+/- 28.7% @ 95% probability) (Table 4). However, comparing only live volumes shows that live volume is underestimated by almost 7% (+/- 28.2% @ 95% probability). A comparison of live + dead volume shows that volume is underestimated by over 21% (+/- 23.9% @ 95% probability).

Representing over 40% of the land base, net merchantable volume in the BL-Mature stratum is underestimated by approximately 68%. Conversely, net merchantable volume in the two other significant strata (PL-Mature and SX-Mature) is overestimated by 39% and 27% respectively. Consistent with the overall mature summaries, the ratios increase when the live or live + dead components are compared. As with past inventory analyses, Phase I volume errors are correlated with basal area estimates. As shown in Table 5, a large component of these volume overestimations is attributable to the impacts of MPB and is discussed further below.

With only two plots, sampling error in DECID-Mature stratum is the highest across all attributes analyzed. This is clearly shown in the sample value plots in Appendix II with a wide distribution of both Phase I and Phase II values across all attributes. Representing only 3% of the land base, this does not pose a significant risk to the overall assessment of the Phase I VRI. However, as discussed earlier, the value of installing low plot counts in a stratum should be evaluated at the VPIP phase and either have additional plots added to the stratum, combine it with another stratum or remove it from the target population. Installing two plots in a stratum provides very little useful information about that stratum, regardless of its size.

Table 4: Analysis Attribute Summary – VDYP Volume

	BL-Mature	DECID-Mature[5]	PL-Mature	SX-Mature	Overall-Mature	Non-THLB	THLB	Immature
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Ratio	0.9643	0.8211	0.9092	0.9748	**0.9501**	0.9528	0.9421	0.9887
Sampling Error	16.5%	36.3%	15.5%	23.3%	**10.5%**	13.3%	13.5%	15.5%
Height (m)								
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Phase I Inventory	14.0	15.1	23.4	20.2	**17.2**	16.2	24.1	8.3
Ratio	1.1569	1.0113	0.9068	0.9914	**1.0150**	1.0610	0.9292	1.3593
Sampling Error	11.9%	77.1%	15.1%	15.0%	**8.3%**	9.5%	15.8%	20.8%
Basal Area (m2/ha) @7.5 cm+ dbh								
n	21	2	13	14	**50**	36	14	20
Phase II Ground	25.4	10.5	26.7	26.3	**25.3**	26.3	22.9	14.1
Phase I Inventory	17.8	19.1	31.2	30.8	**24.8**	20.7	36.0	11.6
Ratio	1.4272	0.5487	0.8569	0.8524	**1.0216**	1.2738	0.6365	1.2189
Sampling Error	29.1%	222.2%	33.3%	35.2%	**19.8%**	22.1%	33.8%	45.3%
Trees / ha @ 7.5cm+ dbh								
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Phase I Inventory	853	803	812	763	**816.1**	823	796	2,124
Ratio	1.4184	0.7496	1.3780	1.3761	**1.3702**	1.4414	1.1821	0.6061
Sampling Error	31.4%	108.2%	43.7%	33.7%	**20.3%**	21.1%	51.9%	64.8%
VDYP7 Volume / ha (m3/ha) @ 12.5 cm+ dbh (net dbw)								
n	21	2	13	14	**50**	36	14	20
Phase II Ground	114.7	39.2	139.6	137.1	**124.0**	126.6	118.8	26.7
Phase I Inventory	68.2	128.0	230.2	186.7	**144.4**	98.3	268.4	15.7
Ratio	1.6807	0.3063	0.6064	0.7345	**0.8590**	1.2886	0.4425	1.7037
Sampling Error	40.2%	181.1%	46.7%	44.4%	**28.7%**	32.5%	39.2%	70.5%
Lorey Height (m)								
n	18	1	13	14	**46**	32	14	11
Phase II Ground	13.8	11.1	17.3	17.1	**14.4**	15.1	17.1	10.8
Phase I Inventory	12.9	23.7	19.7	17.7	**15.1**	14.5	21.1	10.0
Ratio	1.0663	0.4689	0.8754	0.9651	**0.9509**	1.0419	0.8066	1.0781
Sampling Error	13.9%	0.0%	16.8%	16.5%	**8.9%**	10.8%	16.0%	16.3%
Site Index (m)								
n	17	1	9	11	**37**	28	9	12
Phase II Ground	7.9	8.8	11.9	9.2	**9.3**	8.3	12.4	20.7
Phase I Inventory	5.4	10.1	10.9	8.5	**7.9**	6.5	11.5	15.9
Ratio	1.4481	0.8782	1.0923	1.0803	**1.1834**	1.2795	1.0781	1.3021
Sampling Error	21.4%	0.0%	23.7%	24.5%	**13.9%**	16.3%	28.9%	12.8%

[5] Given that this stratum only has two samples and very high sampling error the reader should exercise caution in drawing any conclusions from this information.

Table 5: Volume Analysis Summary – MPB Volume

	BL-Mature	DECID-Mature[6]	PL-Mature	SX-Mature	Overall-Mature	Non-THLB	THLB	Immature
N	21	2	13	14	**50**	36	14	20
Total Area	1,443,981	138,430	860,769	907,872	**3,351,052**			246,880
Live MPB Volume / ha (m3/ha) @ 12.5 cm+ dbh (net dbw)								
n	21	2	13	14	50	36	14	20
Phase II Ground	114.7	39.2	139.6	137.1	124.0	126.6	118.8	26.7
Phase I Inventory	64.5	85.4	149.8	170.9	116.1	92.6	180.8	14.9
Ratio	1.7770	0.4590	0.9319	0.8025	1.0683	1.3672	0.6568	1.7856
Sampling Error	41.7%	181.1%	44.5%	41.9%	28.2%	32.7%	39.8%	71.8%
Live + Dead MPB Volume / ha (m3/ha) @ 12.5 cm+ dbh (net dbw)								
n	21	2	13	14	50	36	14	20
Phase II Ground	143.4	64.7	234.2	187.1	175.3	159.2	219.6	31.7
Phase I Inventory	68.2	128.0	230.2	186.7	144.4	98.3	268.4	15.7
Ratio	2.1018	0.5060	1.0173	1.0024	1.2141	1.6199	0.8183	2.0239
Sampling Error	35.9%	126.4%	30.6%	34.7%	23.9%	29.2%	25.0%	72.0%

The Immature stratum represents 7% of the target population and includes stands as young as 15 years of age. As a result the Phase I average volume is only about 16 m^3/ha and according to the Phase II data underestimates average volume by 70% with high sampling error of 70% even though the plot count is high relative to the area. This is understandable given the inherent variability that can occur in stands this young.

The addition of site index to the list of analyzed attributes provides useful insight into the differences between the Phase I and Phase II populations. As site index plays a considerable role in the development of managed stand yield projections and often factors into the THLB definition in TSR it is important to understand the degree to which the Phase I VRI reasonably reflects site index.

Overall site index is underestimated by approximately 15% (1.4m) in the mature land base and almost 23% (4.8m) in the immature land base. Aside from the DECID-Mature, with only two plots, site index is underestimated in all other strata.

As discussed above, a secondary stratification was explored based on the current THLB definition. This definition was further refined to exclude immature samples with the results included in Table 4. Within the mature samples located inside the THLB, net merchantable volume is overestimated in the Phase I by an average of 56% with a sampling error of 39%. Within the area outside the current THLB, net merchantable volumes are underestimated by almost 29% (+/- 32% @ 95% probability). These volume differences inside and out of the THLB are significant. With volumes outside the THLB increasing while volumes inside the THLB decrease it is difficult to estimate the net impact on the THLB. This is compounded by the economic obstacles to harvesting in many areas of the Mackenzie TSA in that certain stands may not become economical even with these volume adjustments. Given this uncertainty it would be prudent to re-assess the THLB with an adjusted inventory to better understand the overall impact of the Phase I volume error on timber supply.

[6] Given that this stratum only has two samples and very high sampling error the reader should exercise caution in drawing any conclusions from this information.

The original VPIP objective of achieving an overall sampling error of +/-15% (95% probability) on overall net merchantable volume has not been achieved on either the land base as a whole or the mature portion of the land base. This stands to reason as the number of plots installed is significantly lower than the originally proposed 140 plots. In reviewing individual plot records there are several instances where the Phase I and Phase II volume estimates vary considerably with individual plot differences as high as 394 m^3/ha (0161-0048-DO1). As shown in Appendix VII, the Phase I VRI has the correct leading species only 46% of the time which will contribute to the higher sampling error. In addition, this is an extremely large and diverse TSA with a relatively low sampling intensity.

3.2 Model and Attribute-Related Volume Bias

Given the assumption that the Phase II compilations of net merchantable volume are correct, there are two primary potential sources of error that can contribute to the differences between Phase I and Phase II net merchantable volumes: errors in the attributes input into VDYP, and errors in how VDYP calculates net merchantable volume. In this section we attempt to quantify each of these sources of error by inputting the Phase II attribute information into VDYP and comparing the volumes produced with the actual Phase II volumes. It should be noted that the Phase II volumes are produced through a compiler which itself may introduce bias however for the purpose of this analysis we assume this to be negligible.

As indicated by the supplied procedures, this analysis is to be carried out using net merchantable volume at the 7.5+ cm dbh utilization level and therefore the volume information is different than what is report elsewhere in this document. The 7.5 cm utilization level is used to assess bias because it is the primary utilization level used by VDYP 7 and provides the best volume estimate for assessing bias.

Overall, as shown in Table 6 and Figure 2, model-related bias results in an underestimation of volume by approximately 3.2% (4.0 m^3/ha) while the attribute-related bias overestimates volumes by approximately 12% (17.4 m^3/ha) resulting in an overall volume bias of approximately 9.2% (13.4 m^3/ha).

Both model-related and attribute bias was highest (with the exception of the DECID-Mature stratum) in the PL-Mature stratum which may be attributable to the high incidence of mountain pine beetle in this stratum. Across all strata, both model and attribute bias are high. However, because the bias exists both above and below the actual volumes the overall estimates of bias do not give an accurate depiction of the bias.

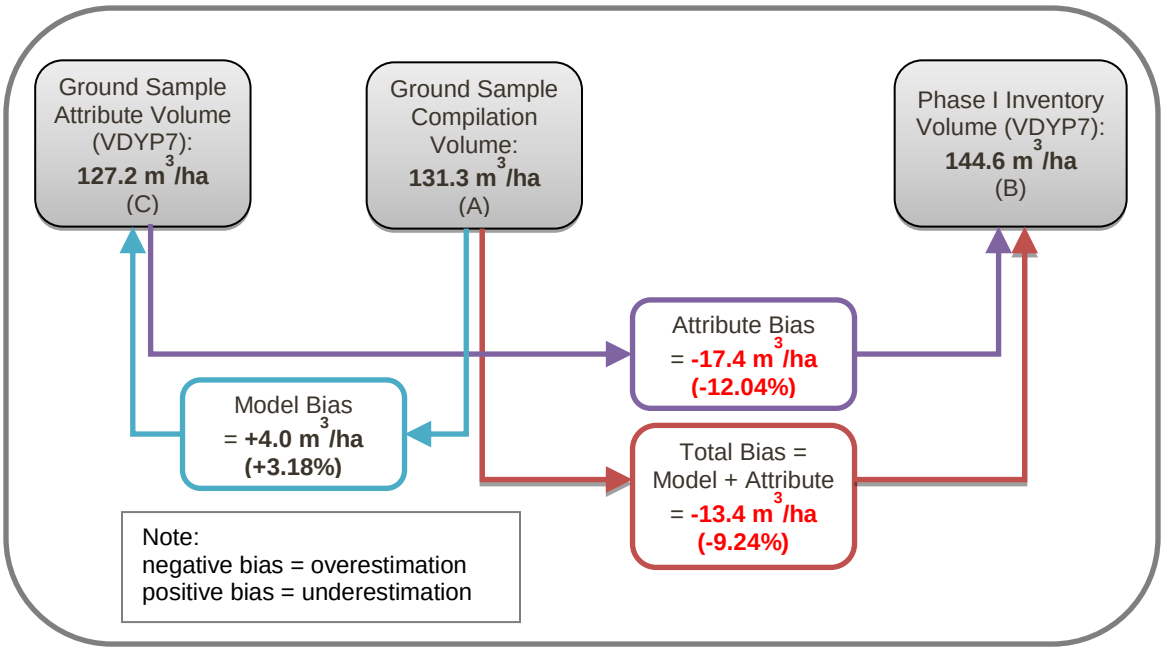

Figure 2: Relationship Between Model and Attribute Bias

Table 6: Analysis of Model and Attribute Bias

	BL-Mature	DECID-Mature	PL-Mature	SX-Mature	Overall[7]
n	21	2	13	14	**50**
Phase II Ground (A)	122.7	47.1	146.8	143.0	**131.3**
Phase I Inventory (B)	68.4	128.1	230.6	186.9	**144.6**
VDYP7 with Phase II Attributes (C)	97.8	48.6	178.1	137.8	**127.2**
Model-Related Volume Bias (A-C)	24.9	-1.5	-31.3	5.2	**4.0**
Attribute-Related Volume Bias (C-B)	29.4	-79.5	-52.5	-49.1	**-17.4**
Total Volume Bias (A-B)	54.3	-80.9	-83.8	-43.9	**-13.4**
Model Bias (A/C)	1.2547	0.9692	0.8243	1.0377	**1.0318**
Sampling Error	12.7%	1.2%	18.8%	18.0%	**8.8%**
Attribute Bias (C/B)	1.4293	0.3795	0.7724	0.7372	**0.8796**
Sampling Error	34.9%	217.8%	38.7%	53.5%	**24.7%**
Total Bias (A/B)	1.7933	0.3679	0.6367	0.7651	**0.9076**
Sampling Error	40.0%	216.5%	42.5%	45.0%	**28.6%**

[7] The Immature stratum is excluded from the analysis of bias due to the limitations of VDYP 7 in predicting volume for young stands.

3.3 Analysis of Dead Volume Estimates

Table 7 compares the amount of dead volume reported in the Phase II ground samples with the overall dead volume reported in the Phase I inventory file. It is important to note that the live and dead volume estimates in the Phase I VRI are based on MPB estimates applied to the inventory after the volumes have been projected using VDYP. These estimates are only intended to capture the mortality due to MPB and therefore only reflect dead pine volume.

Overall, across the entire land base, approximately 19% of the net merchantable Phase I volume is considered to be dead; 20% on the mature land base. The Phase II data shows that approximately 29% of the net merchantable volume is dead. Given this discrepancy it is likely that a component of the Phase I volume overestimation is attributable to volume that is classified as live in the Phase I and dead in the Phase II. This is especially true in SX-Mature strata where the dead volume is underestimated by approximately 19%. Consistent with other units, the dead volume estimates in the pine stratum are much closer to the actual dead volume percentages.

The considerable amount of dead balsam in the Phase II should be noted as this volume will not be captured in the dead volume estimates in the Phase I.

With the MPB infestation still active in the Mackenzie TSA, ongoing monitoring of the dead volume estimates will remain important.

Table 7: Analysis of Dead Volume Estimates

Stratum	Live Volume (m^3/ha)		Dead Volume (m^3/ha)				% Dead Volume			
	Phase II	Phase I	Phase II	Phase II (Pine)	Phase II (Balsam)	Phase I	Phase II	Phase II (Pine)	Phase II (Balsam)	Phase I (Pine)
Immature	26.7	14.9	5.0	4.9	-	0.6	16%	15%	0%	4%
BL-Mature	114.7	64.5	28.7	7.0	18.2	3.5	20%	5%	13%	5%
DECID-Mature	39.2	85.4	25.5	18.4	-	42.6	39%	28%	0%	33%
PL-Mature	139.6	149.8	94.6	72.8	11.4	80.6	40%	31%	5%	35%
SX-Mature	137.1	170.9	50.0	33.1	4.4	15.5	27%	18%	2%	8%
Overall-Mature	**124.0**	**116.1**	**51.3**	**31.4**	**12.0**	**28.1**	**29%**	**18%**	**7%**	**20%**

4 CONCLUSIONS AND RECOMMENDATIONS

This analysis demonstrates that on average, net merchantable volume in the mature portion Mackenzie TSA is overestimated by approximately 14% when the VDYP volumes are compared with the Phase II live volume. However, comparing only live volume shows that volume is underestimated by almost 7% (+/- 28.2% @ 95% probability). If we compare live + dead volume, volume is underestimated by over 21% (+/- 23.9% @ 95% probability). The sampling error of +/- 29% (95% probability) does not meet the stated objective of +/-15% and based on the size of the overestimate relative to the sampling error, caution should be exercised in the application of this information. Sampling errors improve slightly when live and live + dead volumes are compared but all remain above 15%.

The accuracy of basal area estimates continue to coincide with the accuracy of volume estimates and is true for all strata in this analysis. When basal area is overestimated volume is overestimated. When basal area is underestimated volume is underestimated. The relatively high sampling errors in basal area are indicative of the difficulty in reliably photo interpreting this attribute. Given the consistency of this issue from land base to land base the Ministry may wish to investigate modifications to photo interpretation standards to improve the accuracy of this attribute.

Consistent with the above, this analysis quantifies the model versus attribute-related bias reflected in these results and finds an unusually high degree of attribute-related bias within each individual stratum. However, when this bias is summarized into an overall average the excessively high and low bias values in each stratum cancel each other out resulting lower overall bias. Similarly, model bias is variable at the stratum level but averages out to a relatively low number overall.

Although the separation of model and attribute-related bias has only been undertaken on a limited number of units to date, the trends in model and attribute-related bias do not appear to be universal. The Quesnel East analysis (Churlish and Jahraus, 2011) found that model-related bias underestimated volumes by 9% while attribute-related bias overestimated volumes by 40%. In the Strathcona TSA Analysis (Churlish and Jahraus, 2011a) model and attribute-related bias both resulted in an underestimate of volumes on the entire land base but when assessed on only the operable portion of the land base the model-related bias resulted in a very small (<1%) overestimation of volume while the attribute-related bias resulted in an 18% underestimation of volume. In the operable portion of the Fort St. John TSA (Ecora, 2012) model-related bias underestimated volume by 8% while attribute-related bias overestimated volumes by 12%.

As inventory analyses are completed on future units it will be useful to monitor trends in attribute and model-related bias. Through a more detailed and geographically diverse understanding of the trends in bias in estimating volumes, improvements to both photo interpretation procedures and VDYP can improve provincial volume estimates and reduce the risk associated with key decisions such as allowable annual cut determinations. To this end, the ministry may wish to consider completing a project that examines trends in model and attribute-related bias across the entire Province using all of the Phase II data collected to date. This project would provide useful information on

how VDYP might be improved in the future as well as identify consistent trends in attribute-related bias, as well as geographically specific trends in volume estimation bias.

A comparison of dead volume in the TSA shows that on the mature land base the Phase I underestimates dead volume by approximately 9%. In assessing dead volume estimates it is important to understand that Phase I VRI dead volume estimates are the result of a separate process independent of the original Phase I VRI. This process updates live and dead volume in the inventory using existing MPB data but does not update the underlying key inventory attributes that drive VDYP volume projections. Therefore when volumes are projected using VDYP (as in the VRI analysis procedures) the dead volume estimates are not projected. As such, when the ratios between Phase II and Phase I VRI attributes are calculated in the analysis they include Phase II dead volume estimates but do not consider Phase I VRI dead volume adjustments.

With an ever-changing MPB infestation it is also important to understand the difference in timing between the Phase II data collection and the date of the MPB data used to estimate Phase I dead volumes, as well as the relationship between these dates and the status of MPB infestation itself. In this TSA the time difference is minimal with Phase II data collected in 2011 and the Phase I inventory updated for MPB using 2011 data. However, subsequent analyses on this land base must be cognizant of the vintage of the Phase II data relative to the changes in the MPB infestation.

The comparison of Phase I and Phase II dead volume information provides a useful measure of our ability to estimate MPB volume impacts using aerial overview data. For the Mackenzie TSA this provides an exceptionally good assessment because the Phase II and MPB data were both collected in the same year. However, beyond this, and potentially more significant, the amount of dead volume captured in the Phase II data provides an important indicator of the degree to which the results of the inventory analysis are impacted by MPB. In this analysis there is an average of 48 m^3/ha of dead volume in the Phase II data (51 m^3/ha in the mature land base) that is not reflected in the calculated ratios for this analysis. If this volume is included in the inventory analysis, the overall mature net volume ratio goes from 0.86 to 1.21, a change of 35%. This suggests that overall net volumes are underestimated by approximately 21% on the mature land base but that much of this volume is already dead. The fact that much of this dead volume is likely merchantable reinforces the importance of understanding the role that dead volumes play in the analysis.

As the differences between Phase II and Phase I dead volume estimates increase, or more importantly, as the amount of dead volume in the Phase II data increases, the overall ratios in the analysis are impacted by this factor. As shown in this analysis the inclusion of dead volumes can result in a completely different conclusion that if dead volume is excluded. In the future, for units heavily impacted by MPB, the Ministry should consider conducting the inventory analysis using live + dead Phase II volumes and potentially re-compiling the other inventory attributes using live + dead trees. This will result in attribute ratios and analysis results that reflect the overall volume (live + dead) on the land base. This information could then be used to distinguish live versus dead volume.

With limited funding for the Phase II program and a corresponding decrease in sampling intensity it becomes increasingly important that sample locations and stratification be

designed for maximum utility. If we assume that maximum utility is achieved by minimizing the risk and uncertainty associated with the existing volume in AAC determinations then we should focus sampling in areas with the greatest likelihood of being harvested in the near future (50 years). Given this we might re-evaluate how we define the target population and stratification as follows:

- Exclude all areas from the target population in which tenured timber harvesting is not legally authorized:
  - Parks and protected areas;
  - Private land;
  - Indian Reserves and other federal land;
  - Old Growth Management Areas;
  - Riparian reserve zones; and
  - Legally defined habitat areas where timber harvesting is not permitted.
- Exclude areas from the target population in which timber harvesting is unlikely in the next 50 years:
  - Physically inoperable areas;
  - Unstable slopes;
  - Non-VT areas;
  - Low site areas[8];
  - Non-commercial cover[5];
  - Marginally economic species[5];
- Exclude areas from the target population in which VDYP cannot project volumes or where uncertainty is high (stand height of less than 7m, low basal area, too young). Generally this occurs in stands that would not be available for harvest for several decades and therefore represent a low risk to timber supply.
- A minimum number of plots should be established and enforced on each land base to ensure that plot counts are sufficient to provide meaningful information. Strata with plot counts below this number should be allocated more plots, merged with other strata or excluded from the target population. This should happen at the VPIP phase.

In refining the target population it is important to consider the potential impact of the analysis on the factors used to define the target population. For example, you may wish to exclude low site index stands from the target population. However, you may find through the analysis that site index has been drastically underestimated and that you have excluded many stands from the analysis that have a higher site index and should have been included. Similarly, defining the target population based on species composition can be risky given the low accuracy of leading species in some units (46% in this TSA).

By sharpening the focus of the Phase II program and providing more reliable information on a smaller but more significant portion of the land base we likely reduce the sampling

[8] Care should be taken in using these inventory attributes to define the target population as the analysis could show that they perhaps should not have been excluded.

errors associated with inventory analyses as well as the uncertainty associated with inventory volumes in TSR.

5 REFERENCES

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APPENDIX I – ADJUSTMENT DATA

Table 8: Adjustment Data[9]

Stratum	Cluster ID	Phase II Measured Data								Phase I Interpreted Data (Projected to 2011)									Comment
		SPP1	Age	Height	Basal Area	SPH	Net Vol.	Lorey Height	Site Index	SPP1	SPP2	Age	Height	Basal Area	SPH	Net Vol.	Lorey Height	Site Index	
BL-Mature	0161-0001-DO1	BL	76	4.6	0.3	60	-	4.5	4.9	BL	-	112	2.3	5.0	700	-	-	-	no p1 vol; vol set to zero; lht dropped no vdyp lht; si dropped no p1 si;
BL-Mature	0161-0002-DO1	BL	171	10.0	32.4	3,053	74	7.9	4.1	BL	SX	167	6.6	14.0	2,500	-	-	2.6	no p1 vol; vol set to zero; lht dropped no vdyp lht;
BL-Mature	0161-0003-DO1	SX			8.0	464	24	5.4	2.7	BL	SX	152	8.2	0.7	70	1	7	4.4	p2 age blank - age excluded; p2 ht blank - ht excluded;
BL-Mature	0161-0004-DO1	BL	115	15.9	37.8	1,698	173	10.6	8.2	BL	-	162	6.6	14.0	2,500	-	-	2.7	no p1 vol; vol set to zero; lht dropped no vdyp lht;
BL-Mature	0161-0005-DO1	BL	257	11.9	14.0	851	54	10.8	3.4	BL	-	153	10.0	6.7	818	5	7	4.0	
BL-Mature	0161-0006-DO1	BL	79	15.4	25.2	739	142	12.4	12.1	BL	SX	126	8.5	3.6	533	1	7	4.2	
BL-Mature	0161-0007-DO1	BL	-		5.4	26	34	19.0	13.2	BL	-	145	13.5	3.6	165	11	11	5.7	p2 age blank - age excluded; p2 ht blank - ht excluded;
BL-Mature	0161-0008-DO1	S	159	14.0	32.2	1,282	129	11.2	6.7	BL	-	206	13.4	8.1	404	22	10	-	si dropped no p1 si; si dropped failed si spp match;
BL-Mature	0161-0009-DO1	BL	145	18.3	23.8	1,130	102	13.8	8.7	BL	SX	177	19.4	6.0	221	31	17	7.2	
BL-Mature	0161-0010-DO1	BL	282	17.4	32.4	2,637	80	14.4	3.6	BL	SX	168	12.8	20.7	639	51	11	4.6	
BL-Mature	0161-0011-DO1	BL	267	18.1	32.2	1,042	173	12.9	4.8	BL	-	186	11.4	8.1	796	11	8	3.6	
BL-Mature	0161-0012-DO1	S	126	14.0	15.0	141	91	13.9	8.5	BL	PL	170	13.3	7.5	347	33	15	-	si dropped no p1 si; si dropped failed si spp match;
BL-Mature	0161-0013-DO1	SW	78	17.0	19.0	606	85	13.4	14.3	BL	SX	135	17.6	38.0	1,448	164	15	8.7	
BL-Mature	0161-0014-DO1	BL	225	22.3	40.6	1,173	240	14.5	7.8	BL	SX	195	22.3	30.1	801	172	18	8.1	
BL-Mature	0161-0015-DO1	BL	205	9.9	21.0	1,980	56	12.6	3.9	BL	SX	232	15.8	25.0	744	75	12	4.0	
BL-Mature	0161-0016-DO1	BL	264	20.5	48.0	2,266	231	18.0	5.8	BL	SW	205	16.4	32.0	1,001	144	15	4.8	
BL-Mature	0161-0017-DO1	BL	133	16.9	23.8	234	187	21.8	8.7	BL	SX	206	18.4	35.0	752	153	15	5.6	
BL-Mature	0161-0018-DO1	BL	127	18.3	28.8	2,166	86	9.2	9.9	BL	SX	156	18.6	39.4	1,362	183	15	7.7	
BL-Mature	0161-0019-DO1	S	88	17.4	23.3	1,166	83	12.0	14.8	BL	SX	166	17.5	30.3	655	148	16	5.9	
BL-Mature	0161-0020-DO1	BL	162	19.0	46.8	2,409	212	12.2	7.4	BL	SX	125	16.6	19.8	778	85	15	8.5	
BL-Mature	0161-0021-DO1	S	111	27.4	22.4	286	151	20.2	15.9	BL	PL	135	18.6	25.6	680	142	18	-	si dropped no p1 si; si dropped failed si spp match;
DECID-Mature	0161-0049-DO1	PL	40	10.5	13.0	895	36	10.3	17.3	AT	BL	62	4.5	2.0	750	-	-		no p1 vol; vol set to zero; lht dropped no vdyp lht; si dropped no p1 si; si dropped failed si spp match;
DECID-Mature	0161-0050-DO1	AT	81	20.0	8.0	309	42	11.1	17.7	AT	PL	85	25.7	36.3	856	256	24	20.1	
Immature	0161-0051-MO1	PL	29	13.2	14.2	1,226	29	9.8	21.8	PL	AT	35	9.8	6.9	727	7	9	15.0	
Immature	0161-0052-MO1	PL	32	15.5	11.7	700	51	13.8	23.1	PL	SX	22	9.4	4.5	495	4	9	21.0	
Immature	0161-0053-MO1	AT	47	14.0	10.7	1,476	10	11.1	13.9	PL	AT	46	13.7	16.2	1,283	36	11	14.7	
Immature	0161-0054-MO1	PL	48	16.2	23.0	2,176	65	13.2	18.3	PL	SX	50	16.2	28.6	2,577	80	14	17.6	
Immature	0161-0055-MO1	S	24	4.3	-	-	-	3.8	17.4	PL	AT	21	7.9	5.0	2,500	-	-	-	no p1 vol; vol set to zero; lht dropped no vdyp lht; si dropped no p1 si; si dropped failed si spp match;
Immature	0161-0056-MO1	PL	25	11.3	24.8	2,327	35	10.3	21.6	PL	SW	39	12.0	14.8	1,380	28	10	16.0	
Immature	0161-0057-MO1	BL	23	6.0	4.3	575	0	5.0	17.3	PL	S	41	12.4	14.5	1,243	29	11	-	si dropped no p1 si; si dropped failed si spp match;
Immature	0161-0058-MO1	PL	39	15.3	25.0	2,777	37	12.4	20.3	PL	AT	39	10.9	22.8	3,362	10	9	15.0	
Immature	0161-0059-MO1	S	25	10.1	12.5	1,251	10	8.1	22.5	PL	S	29	6.4	7.3	850	6	8	9.3	
Immature	0161-0060-MO1	BL	26	7.8	7.5	851	5	7.1	19.3	SW	BL	22	2.8	-			-	14.3	no p1 vol; vol set to zero; lht dropped no vdyp lht;
Immature	0161-0061-MO1	AT	36	15.4	27.1	1,951	80	13.1	22.2	SX	BL	36	11.3	15.0	1,623	17	9	-	failed spp match; si dropped no p1 si; si dropped failed si spp match;
Immature	0161-0062-MO1	BL	55	14.3	32.6	2,502	84	10.3	16.5	SX	BL	28	6.3	-	-	-	-	17.1	p1 sph blank - sph set to zero; no p1 vol; vol set to zero; lht dropped no vdyp lht;
Immature	0161-0063-MO1	SW	27	9.7	28.7	1,951	57	8.8	22.2	SW	PL	40	7.5	5.0	2,000	-	-	15.0	no p1 vol; vol set to zero; lht dropped no vdyp lht;
Immature	0161-0064-MO1	SW	22	8.6	7.8	600	8	7.0	25.5	SX	-	16	1.7	-	1,500	-	-	21.0	no p1 vol; vol set to zero; lht dropped no vdyp lht;
Immature	0161-0065-MO1	SW	25	9.2	11.1	1,251	6	7.6	23.5	SW	AC	27	3.6	10.0	1,800	-	-	15.0	no p1 vol; vol set to zero; lht dropped no vdyp lht;
Immature	0161-0066-MO1	0	-	-	-	-	-	-	-	BL	-	40	2.5	2.0	6,000	-	-	-	failed spp match; p2 ba blank - ba set to zero; p2 sph blank - sph set to zero; p2 vol blank - vol set to zero; no p1 vol; vol set to zero; lht dropped no vdyp lht; si dropped no p1 si; si dropped failed si spp match;
Immature	0161-0068-MO1	S	30	12.4	9.9	525	25	10.0	25.7	AT	PL	30	8.3	38.3	2,248	64	9		si dropped no p1 si; si dropped failed si spp match;
Immature	0161-0069-MO1	PL	30	10.0	12.3	1,076	17	8.2	18.3	AT	SW	22	3.3	25.0	11,589	-	-		no p1 vol; vol set to zero; lht dropped no vdyp lht; si dropped no p1 si; si dropped failed si spp match;
Immature	0161-0070-MO1	PL	32	14.9	19.1	2,527	14	12.5	22.5	EP	S	39	9.5	14.0	997	31	12	-	si dropped no p1 si; si dropped failed si spp match;
Immature	0161-0112-MO1	0	-	-	-	-	-	-	-	BL	-	35	4.2	2.0	300	-	-	-	failed spp match; p2 ba blank - ba set to zero; p2 sph blank - sph set to zero; no p1 vol; vol set to zero; lht dropped no vdyp lht; si dropped no p1 si; si dropped failed si spp match;
PL-Mature	0161-0036-DO1	S	71	9.7	1.4	162	-	6.4	14.7	PL	SX	126	23.0	9.8	216	83	22	14.1	
PL-Mature	0161-0037-DO1	PL	162	19.6	25.2	926	133	16.1	9.3	PL	S	238	16.7	23.7	1,122	98	14	7.9	

[9] Shaded cells are outside the THLB based on the plot list provided by Barry Snowden October 25th, 2012.

Stratum	Cluster ID	Phase II Measured Data								Phase I Interpreted Data (Projected to 2011)								Comment
		SPP1	Age	Height	Basal Area	SPH	Net Vol.	Lorey Height	Site Index	SPP1	SPP2	Age	Height	Basal Area	SPH	Net Vol.	Lorey Height	Site Index	
PL-Mature	0161-0038-DO1	BL	144	20.7	46.8	1,447	283	18.8	11.2	PL	BL	125	19.3	18.7	1,194	71	14	7.9	
PL-Mature	0161-0039-DO1	BL	62	9.8	4.0	334	10	11.5	12.1	PL	-	102	15.0	9.4	417	49	13	-	si dropped no p1 si; si dropped failed si spp match;
PL-Mature	0161-0040-DO1	BL	234	16.6	46.8	2,538	195	11.1	5.4	PL	BL	187	29.3	35.4	752	223	19	6.7	
PL-Mature	0161-0041-DO1	SB	183	18.4	11.2	756	33	17.2	7.9	PL	-	135	20.3	35.3	1,227	219	17	-	si dropped no p1 si; si dropped failed si spp match;
PL-Mature	0161-0042-DO1	S	130	27.6	45.0	832	259	19.7	15.3	PL	SX	184	23.8	26.1	609	200	21	7.2	
PL-Mature	0161-0043-DO1	S	184	32.4	23.4	654	144	19.4	12.3	PL	SX	205	27.1	30.0	400	247	24	8.3	
PL-Mature	0161-0044-DO1	BL	113	25.8	25.2	328	183	23.0	16.3	PL	SX	161	32.3	34.9	640	281	23	-	si dropped no p1 si; si dropped failed si spp match;
PL-Mature	0161-0045-DO1	EP	90	24.5	30.8	1,991	127	19.2	-	PL	AT	95	23.5	36.0	951	274	21	-	si dropped no p1 si; si dropped failed si spp match;
PL-Mature	0161-0046-DO1	S	137	23.0	11.2	407	62	18.9	12.0	PL	SX	125	24.3	47.4	1,072	392	22	13.6	
PL-Mature	0161-0047-DO1	S	128	26.3	41.4	953	272	26.5	13.8	PL	SW	140	23.3	44.2	1,052	349	22	13.1	
PL-Mature	0161-0048-DO1	PL	135	22.1	35.0	3,215	113	16.8	13.0	PL	SW	125	27.0	54.6	902	507	24	19.2	
SX-Mature	0161-0022-DO1	BL	221	14.1	18.2	833	83	11.9	4.6	SX	BL	210	17.1	14.9	449	47	12	3.0	
SX-Mature	0161-0023-DO1	SX	286	16.6	14.0	524	64	8.4	3.5	SX	BL	122	17.8	16.1	367	75	15	9.1	
SX-Mature	0161-0024-DO1	BL	128	21.6	18.7	573	126	23.2	10.5	S	SB	238	17.9	7.6	372	24	13	-	si dropped no p1 si; si dropped failed si spp match;
SX-Mature	0161-0025-DO1	BL	211	23.0	39.6	1,710	191	18.1	7.4	SX	BL	192	12.3	9.9	832	29	14	5.0	
SX-Mature	0161-0026-DO1	S	161	16.2	16.0	548	77	14.3	6.0	SX	BL	162	21.3	38.2	869	193	17	8.4	
SX-Mature	0161-0027-DO1	BL	137	13.9	34.2	1,848	140	16.5	5.9	SX	BL	170	17.3	24.9	649	122	17	5.7	
SX-Mature	0161-0028-DO1	BL	214	23.3	46.2	2,728	207	17.4	6.9	SX	BL	122	17.2	36.5	1,155	196	17	9.2	
SX-Mature	0161-0029-DO1	S	81	16.1	24.5	1,394	88	13.4	15.9	SX	AC	135	20.7	21.0	503	120	20	9.8	
SX-Mature	0161-0030-DO1	S	237	24.1	41.4	882	235	21.0	8.0	SX	BL	222	18.0	31.6	1,374	106	13	4.7	
SX-Mature	0161-0031-DO1	AT	104	23.9	19.8	430	133	19.5	17.4	SW	PL	156	28.6	54.7	875	439	23	-	failed spp match; si dropped no p1 si; si dropped failed si spp match;
SX-Mature	0161-0032-DO1	BL	121	22.7	32.4	1,442	179	21.4	13.6	SX	BL	136	22.4	64.6	1,200	413	21	12.4	
SX-Mature	0161-0033-DO1	SW	90	26.4	8.4	95	54	18.8	19.5	SX	PL	135	25.6	30.5	686	235	22	13.2	
SX-Mature	0161-0034-DO1	BL	112	23.3	36.0	955	248	21.8	15.1	SX	AT	173	26.7	35.8	630	258	22	-	si dropped no p1 si; si dropped failed si spp match;
SX-Mature	0161-0035-DO1	S	119	18.5	18.2	747	94	14.2	9.9	SX	PL	156	27.6	44.8	728	357	23	12.9	

APPENDIX II – PHOTO VS. GROUND PLOTS

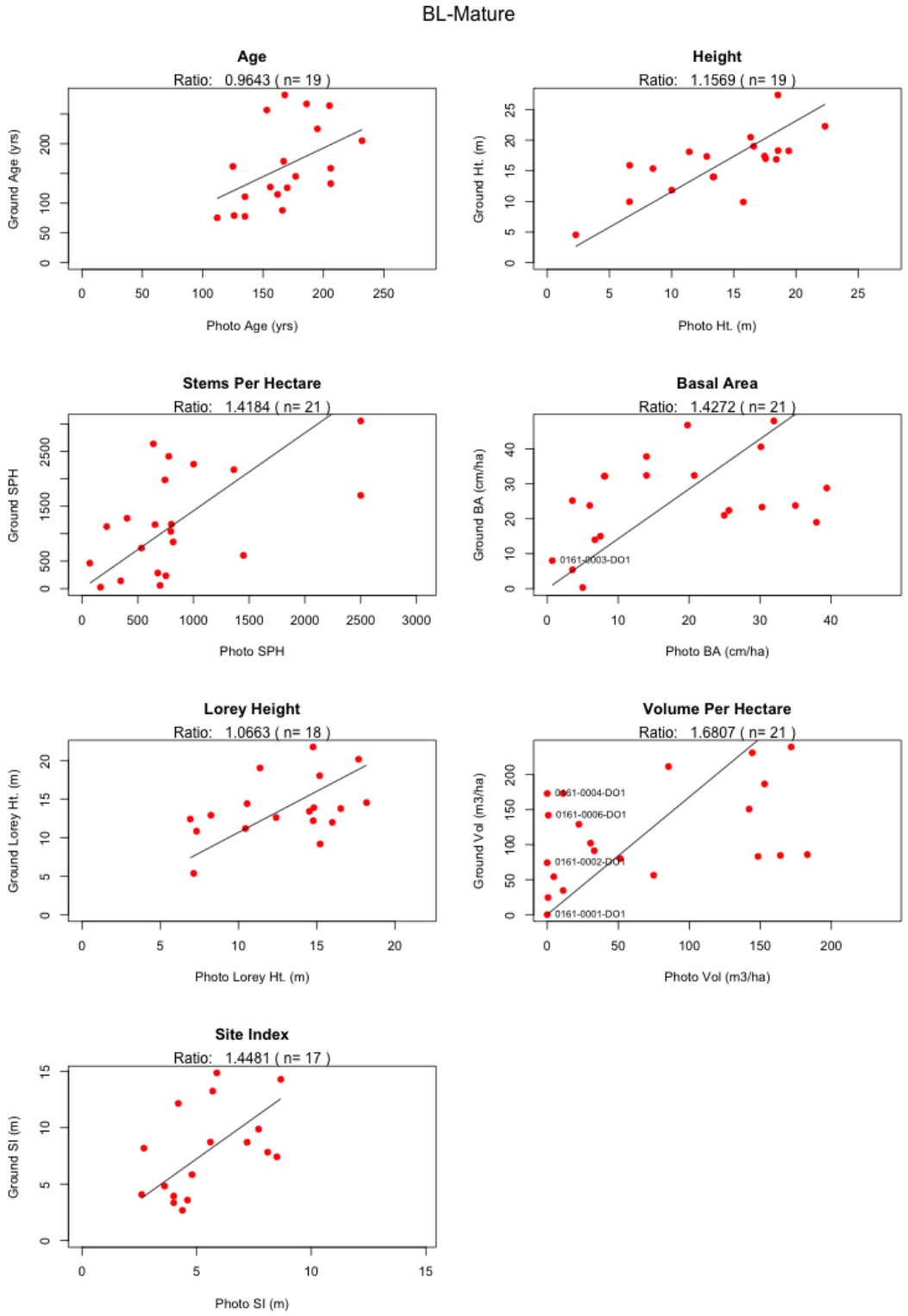

Figure 3: BL-Mature Stratum – Attribute Values

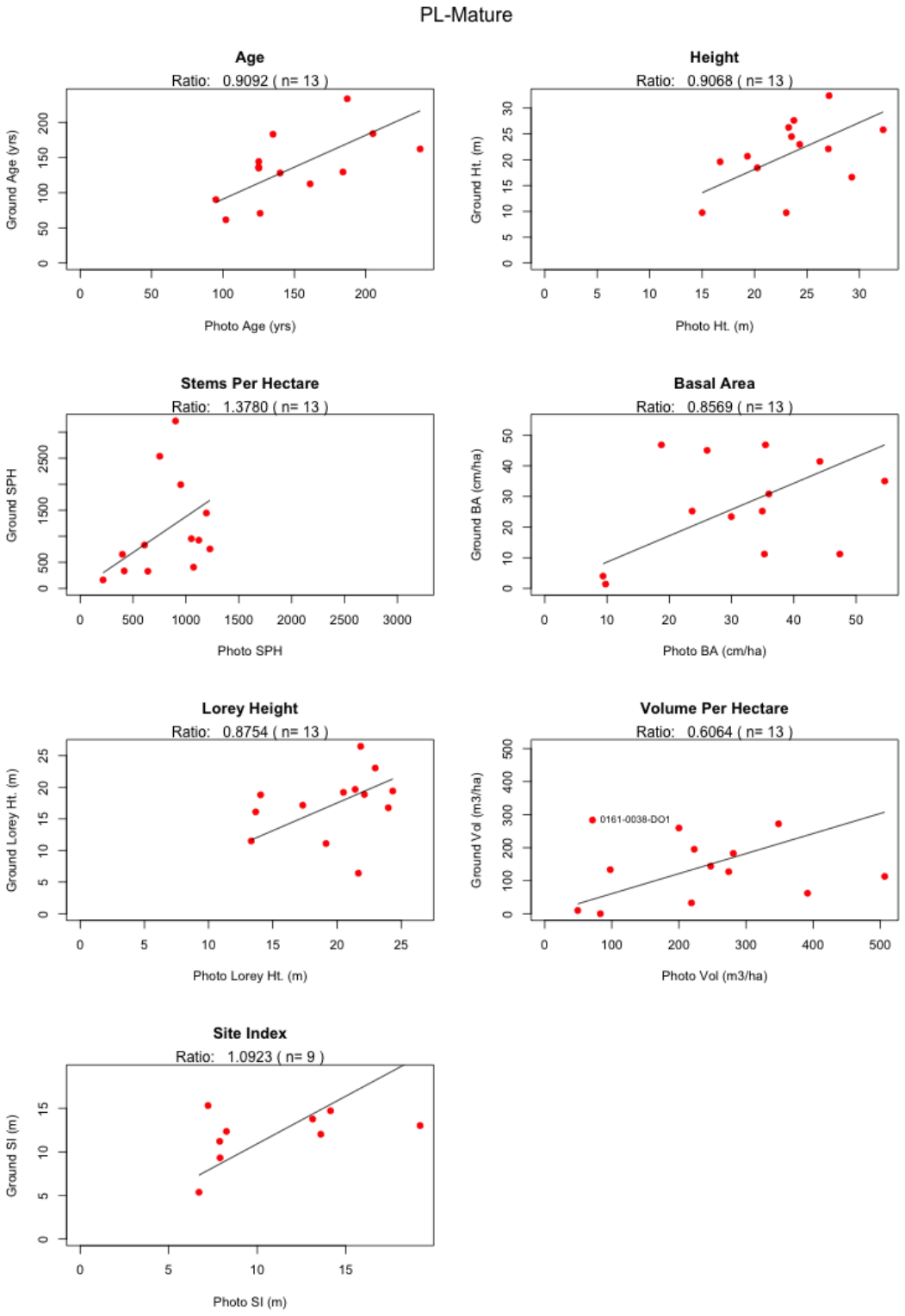

Figure 4: PL-Mature Stratum – Attribute Values

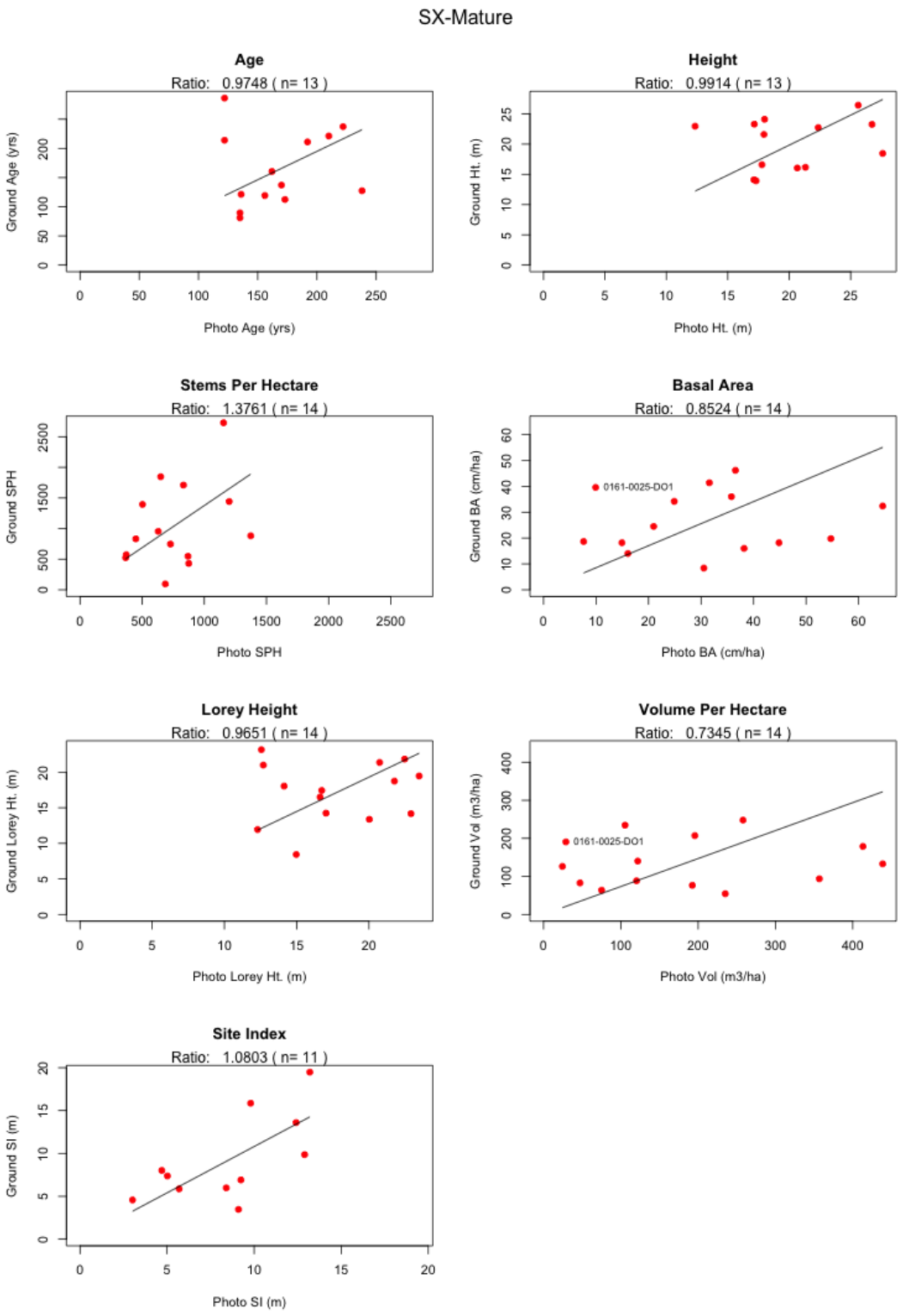

Figure 5: SX-Mature Stratum – Attribute Values

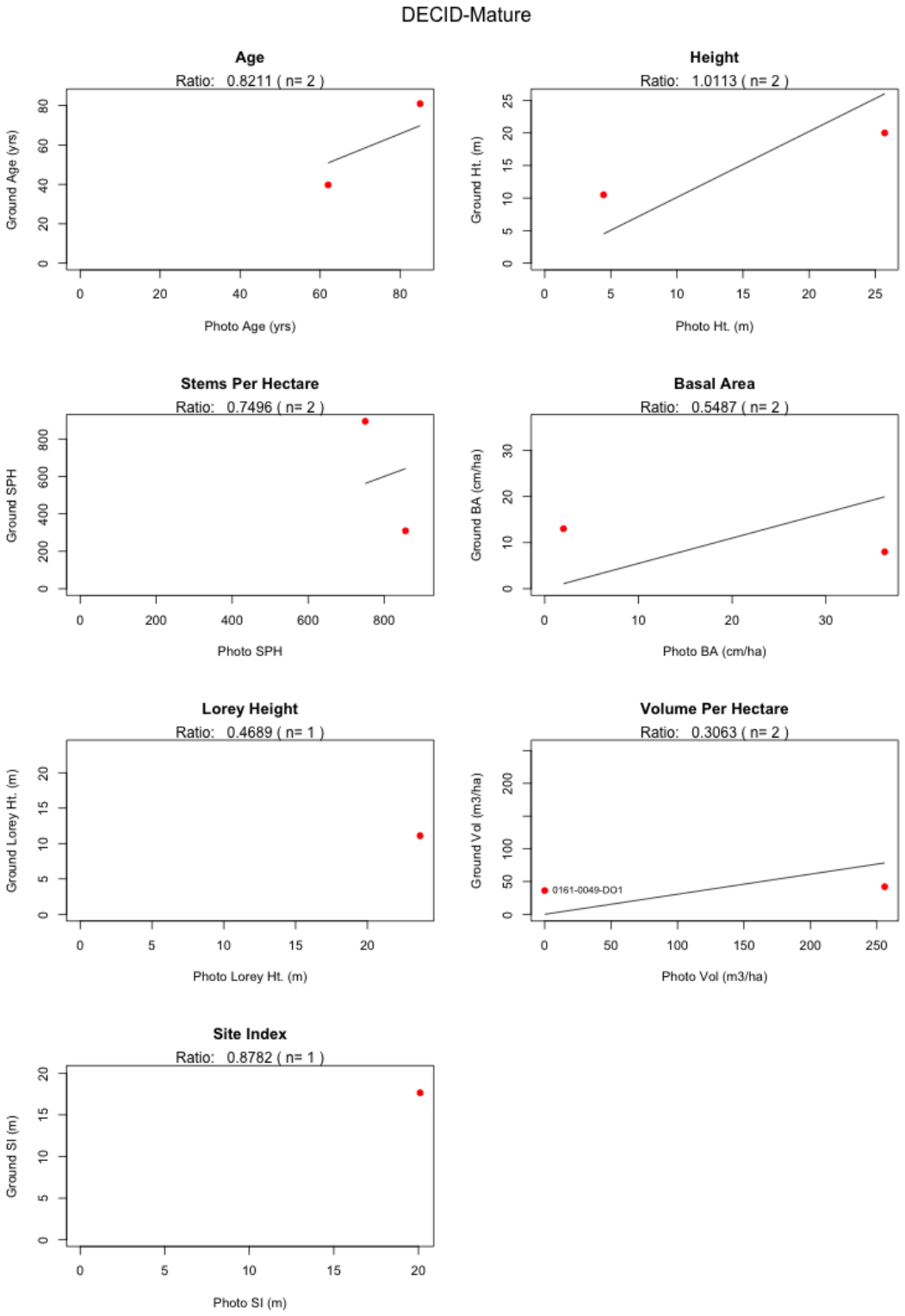

Figure 6: DECID-Mature Stratum – Attribute Values

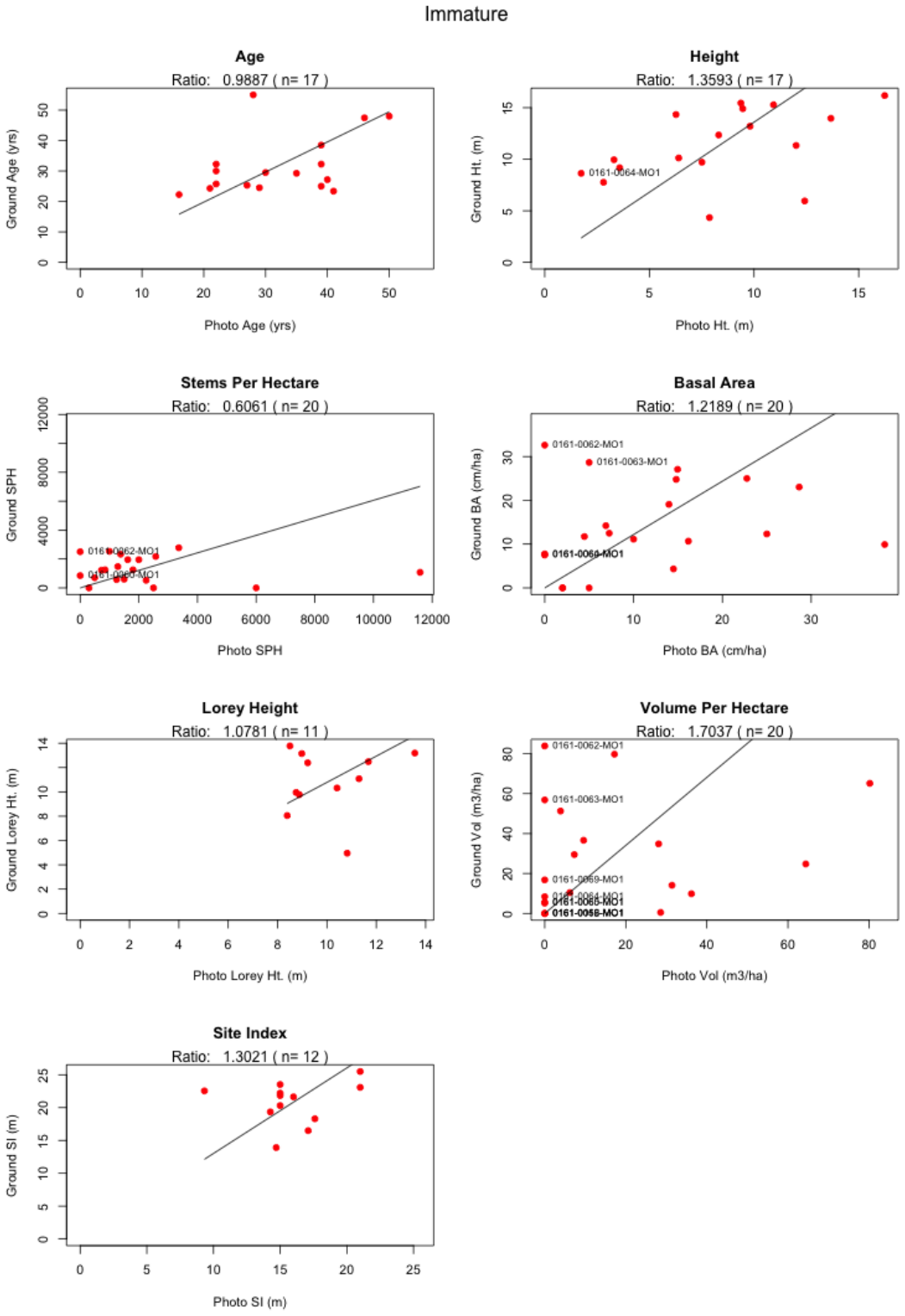

Figure 7: Immature Stratum – Attribute Values

APPENDIX III – PLOT RATIOS AND POTENTIAL OUTLIERS

BL-Mature

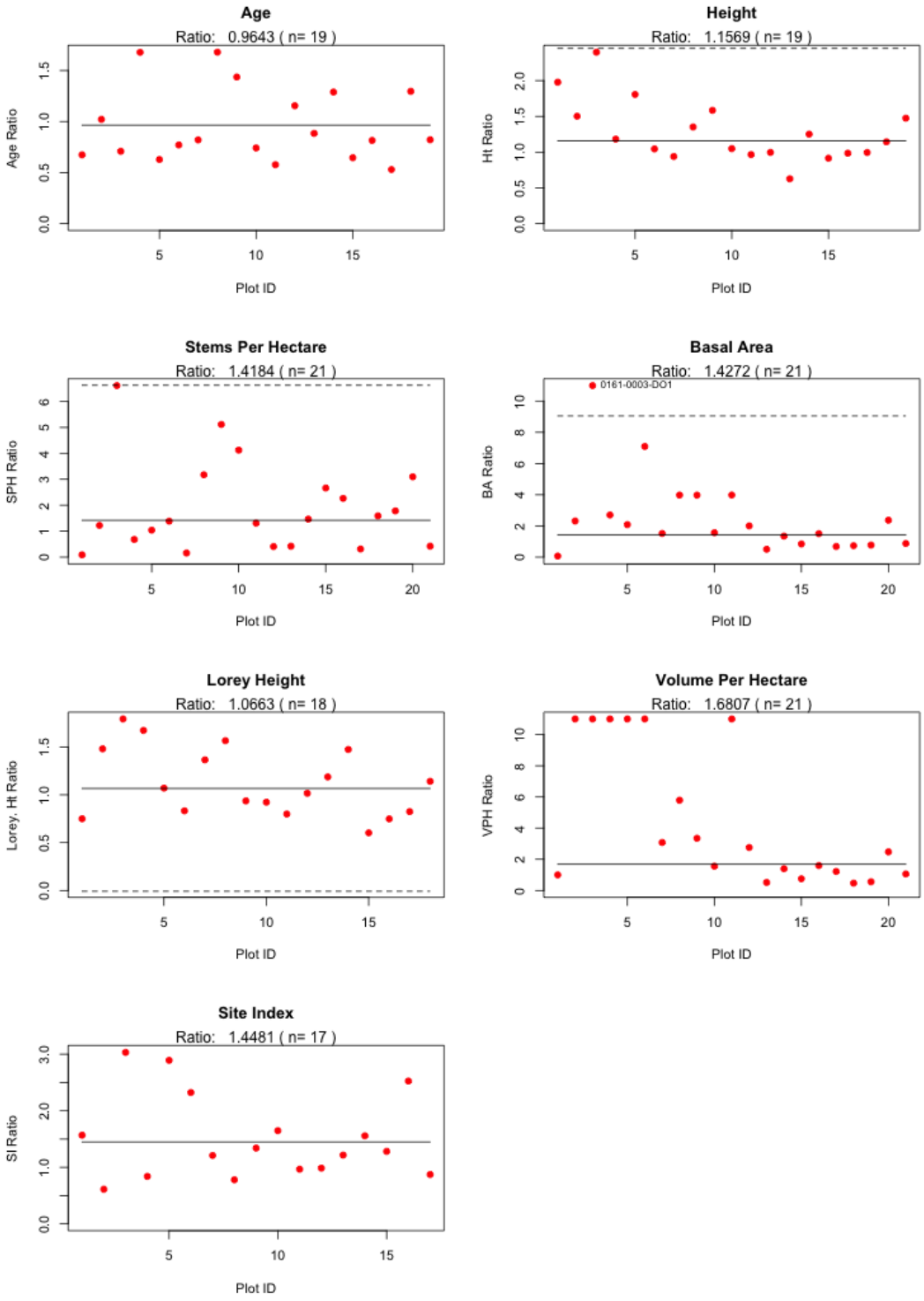

Figure 8: BL-Mature Stratum – Plot Ratios

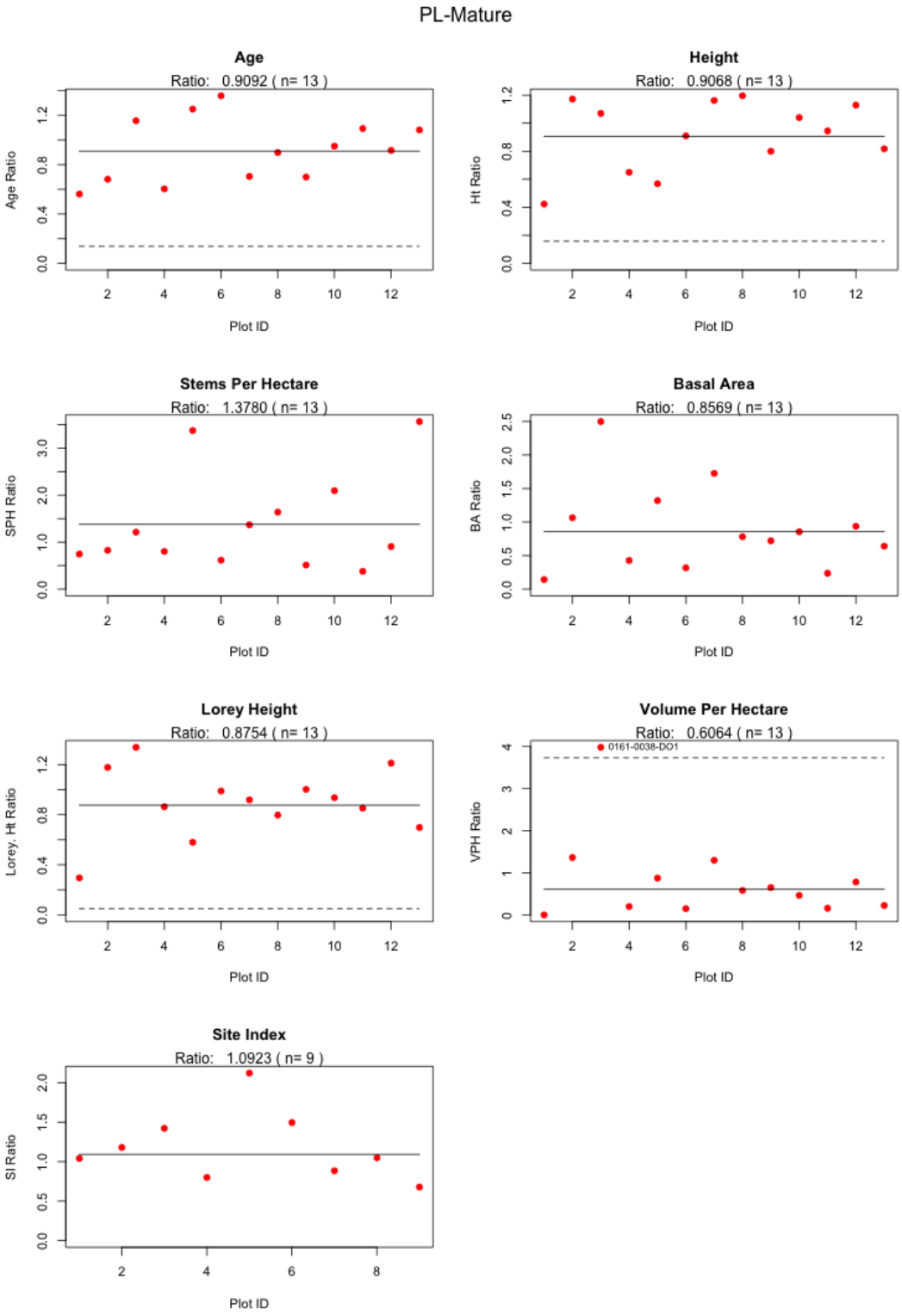

Figure 9: PL-Mature Stratum – Plot Ratios

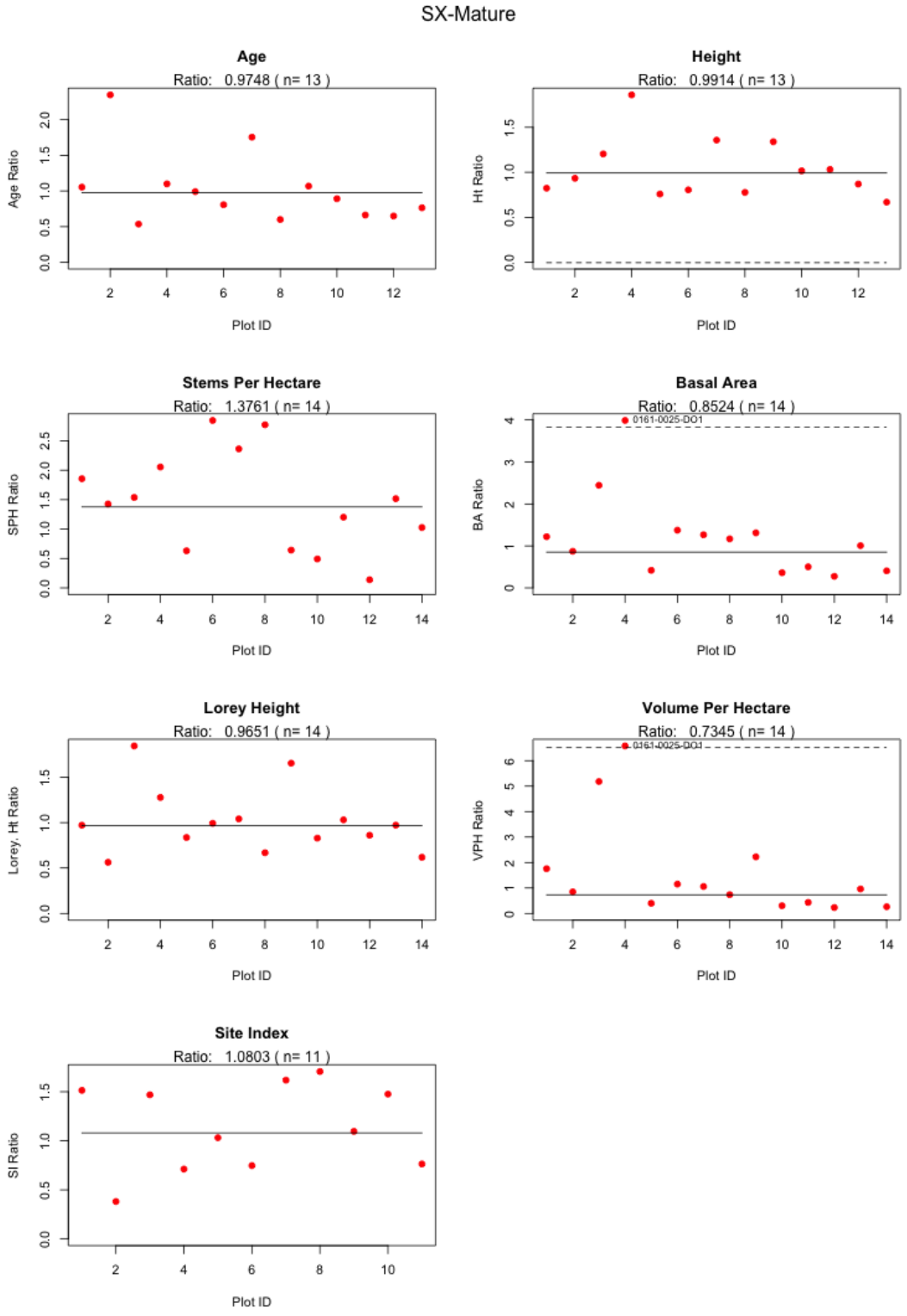

Figure 10: SX-Mature Stratum – Plot Ratios

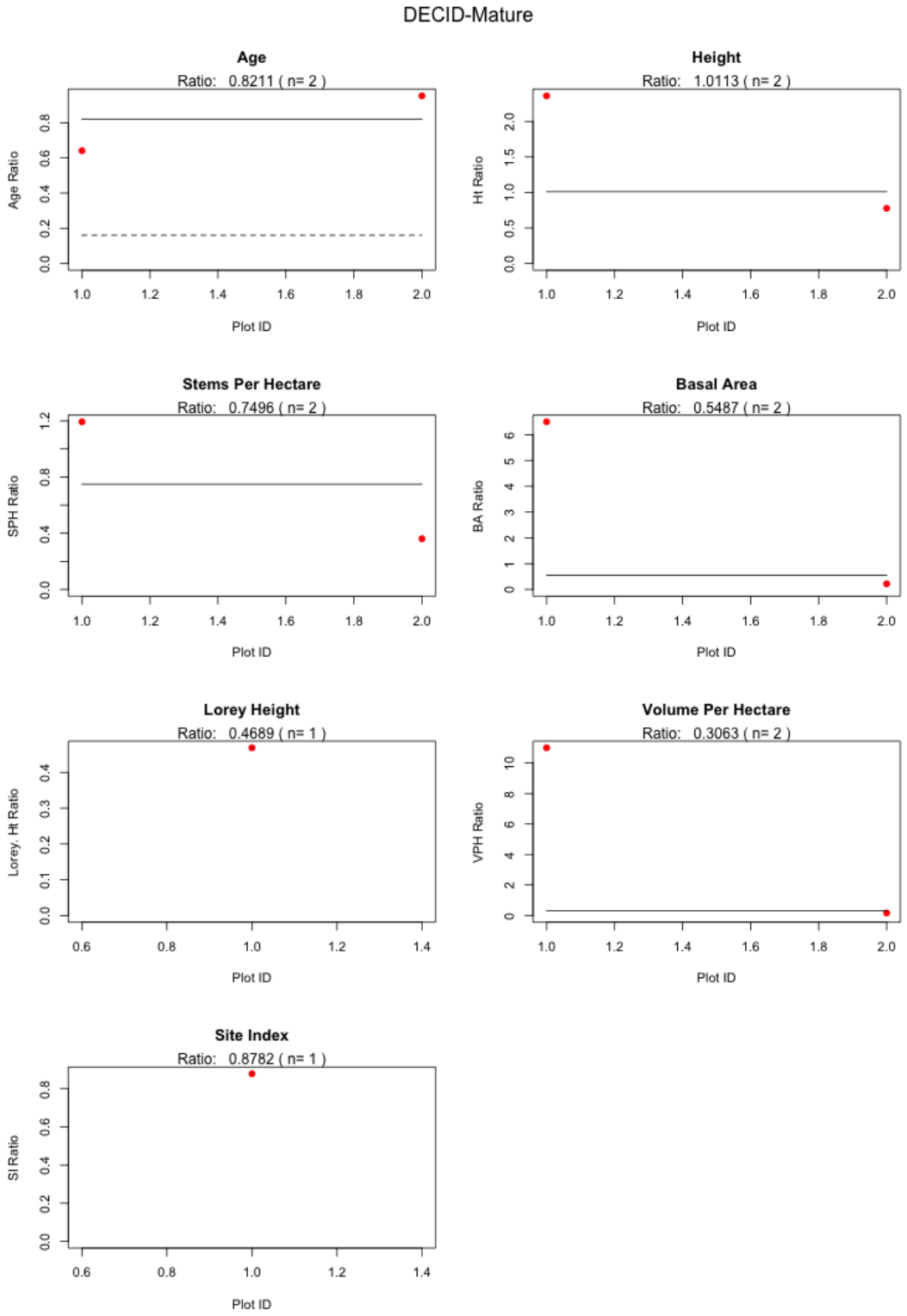

Figure 11: DECID-Mature Stratum – Plot Ratios

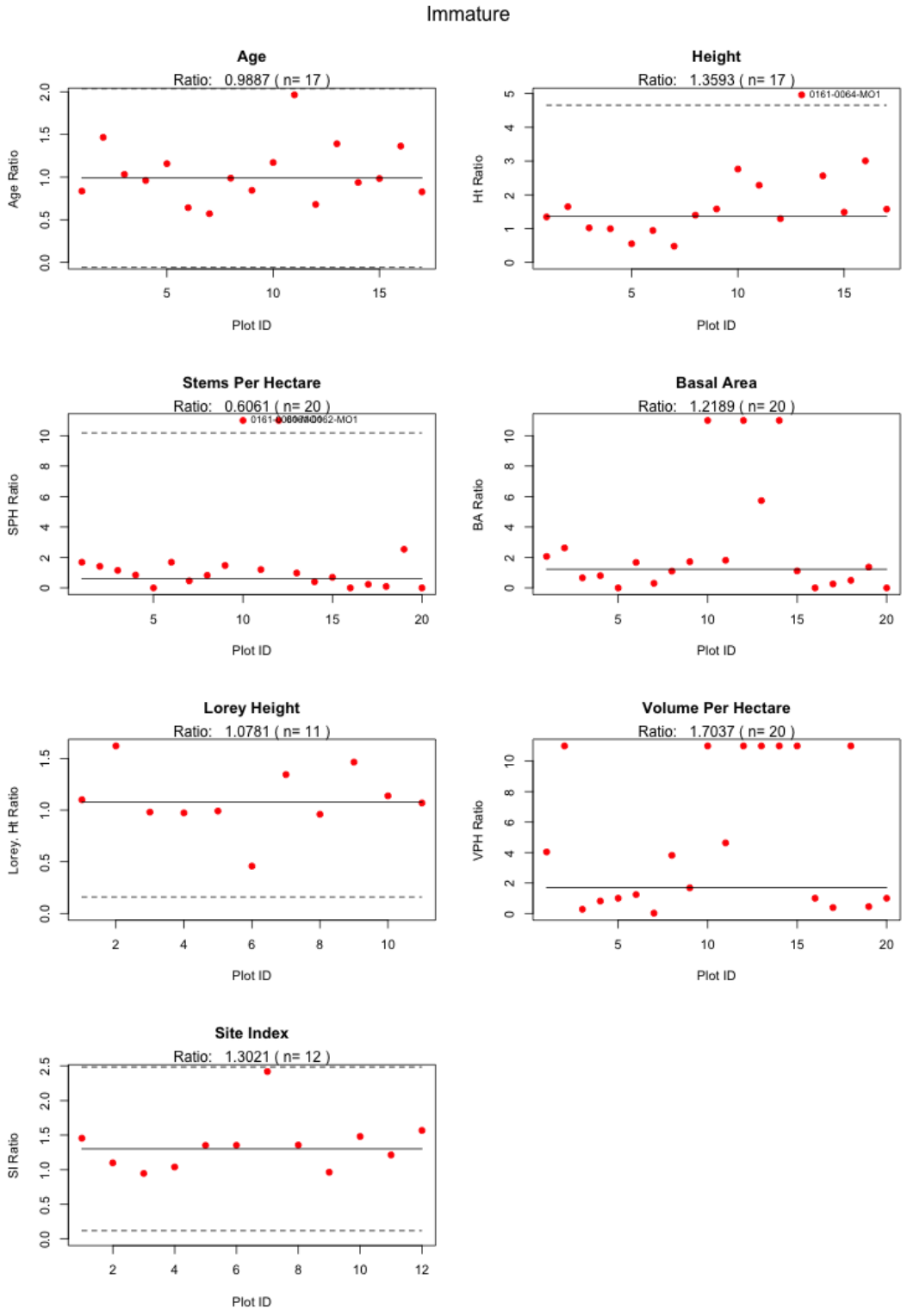

Figure 12: Immature Stratum – Plot Ratios

APPENDIX IV – RESIDUAL VALUES

BL-Mature

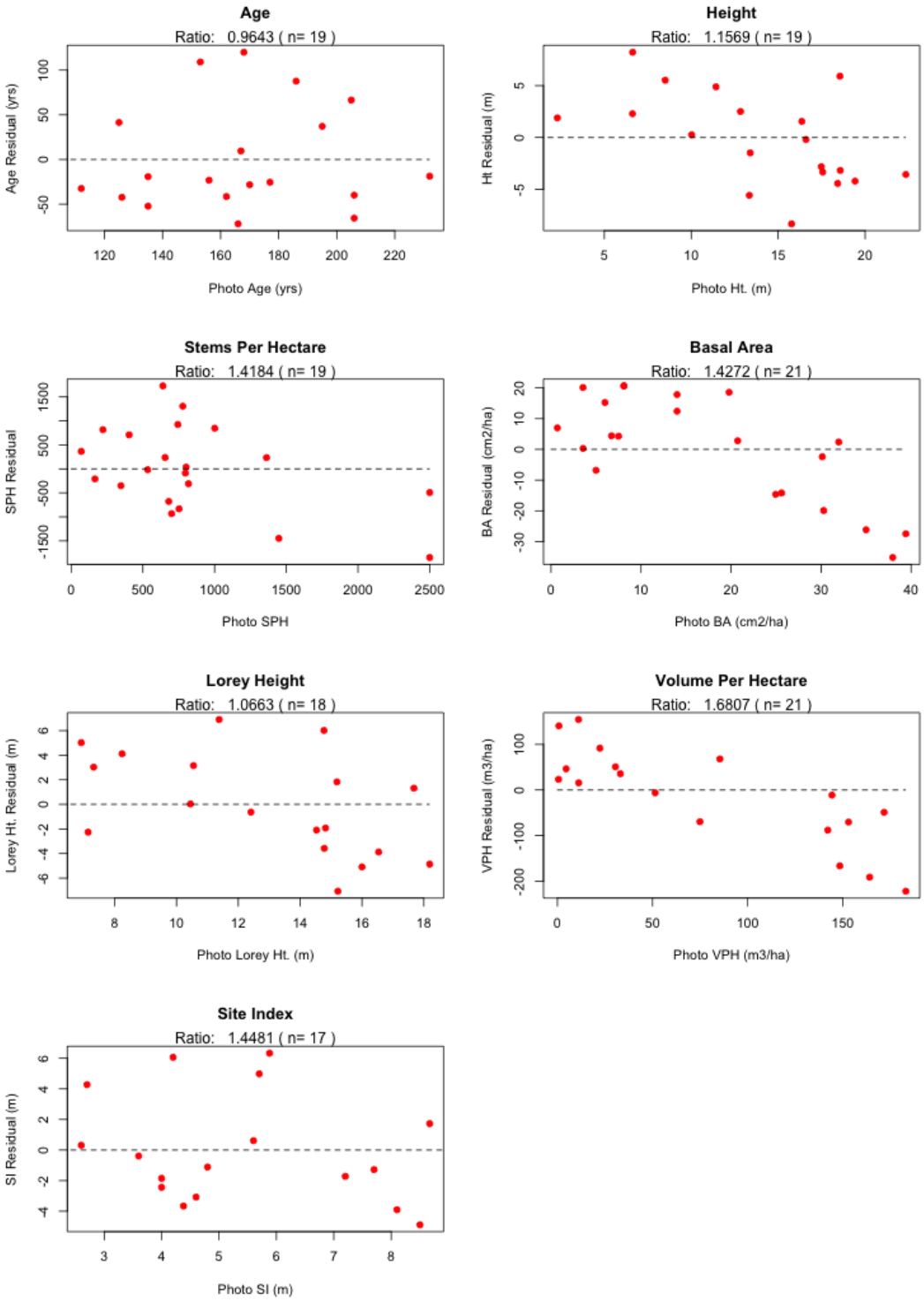

Figure 13: BL-Mature Stratum – Residual Values

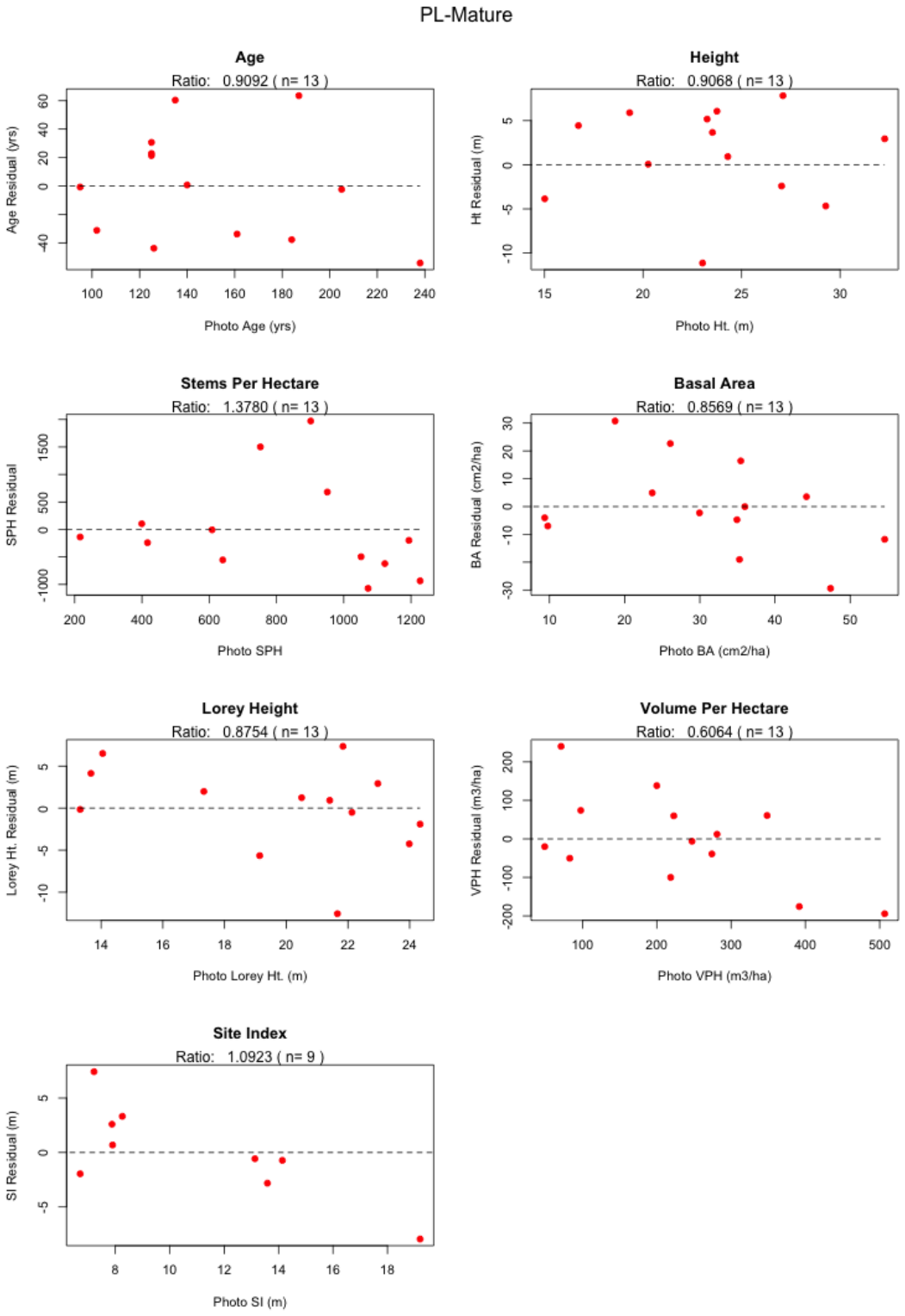

Figure 14: PL-Mature Stratum – Residual Values

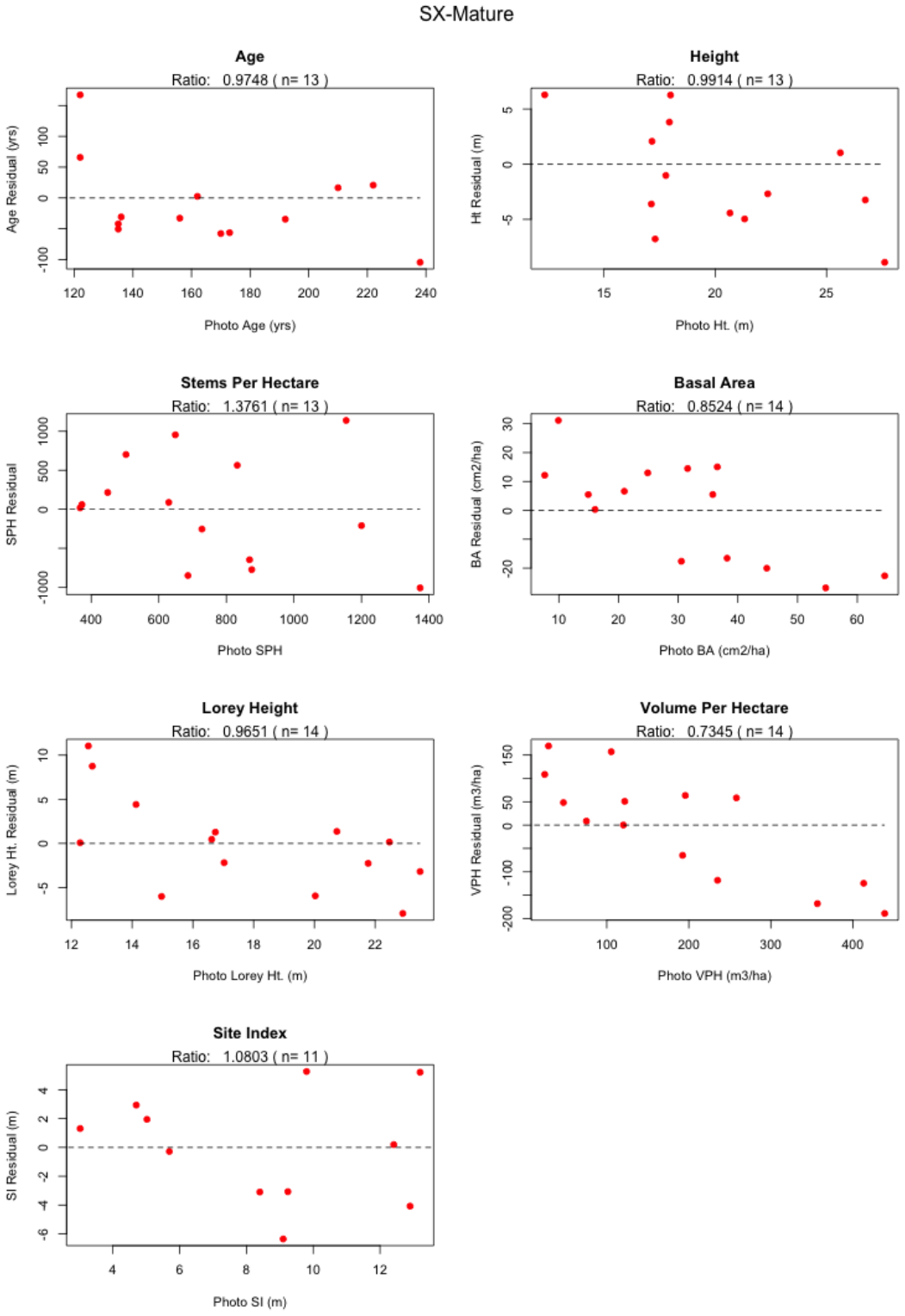

Figure 15: SX-Mature Stratum – Residual Values

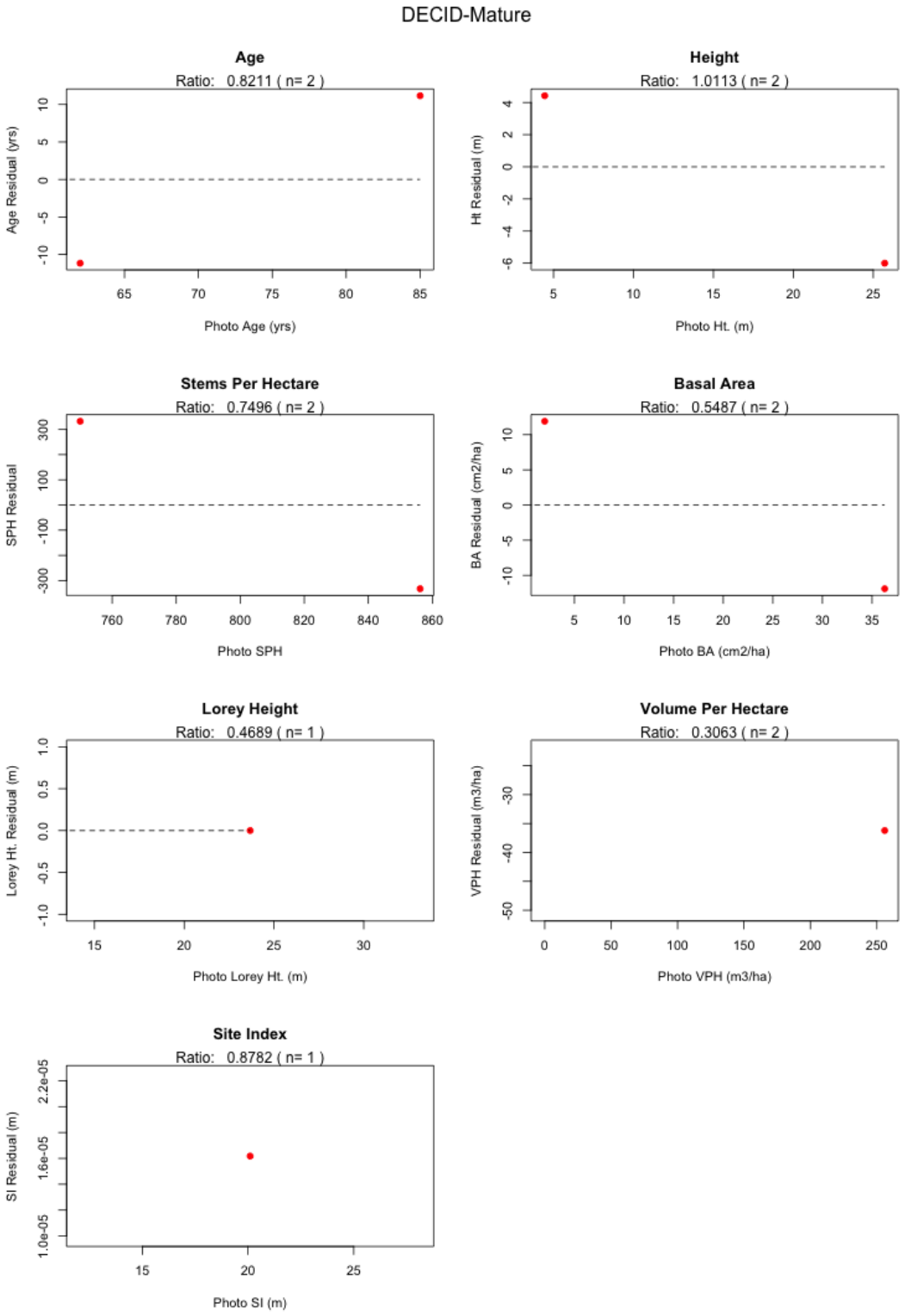

Figure 16: DECID-Mature Stratum – Residual Values

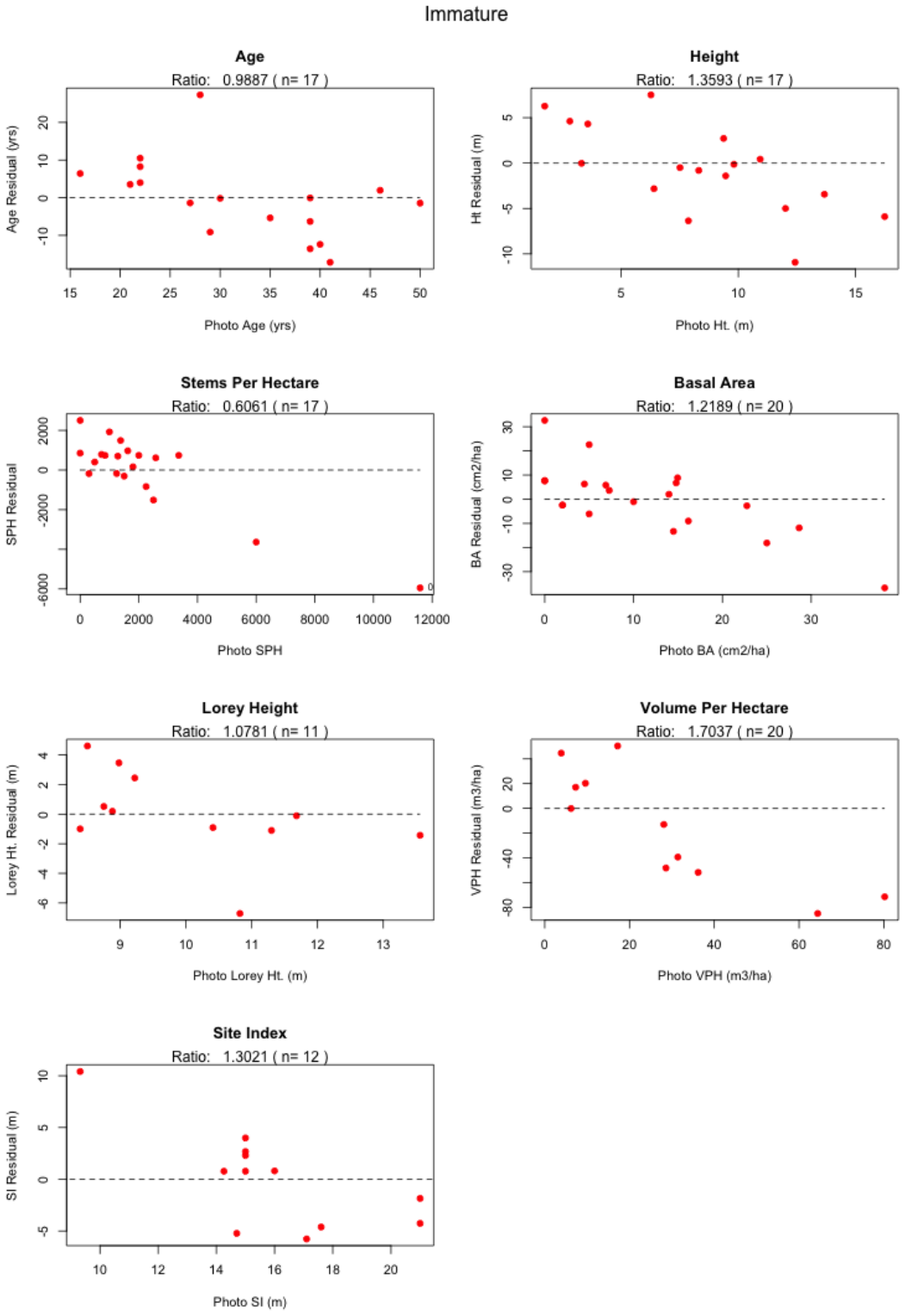

Figure 17: Immature Stratum – Residual Values

APPENDIX V – ATTRIBUTES AND POTENTIAL OUTLIERS

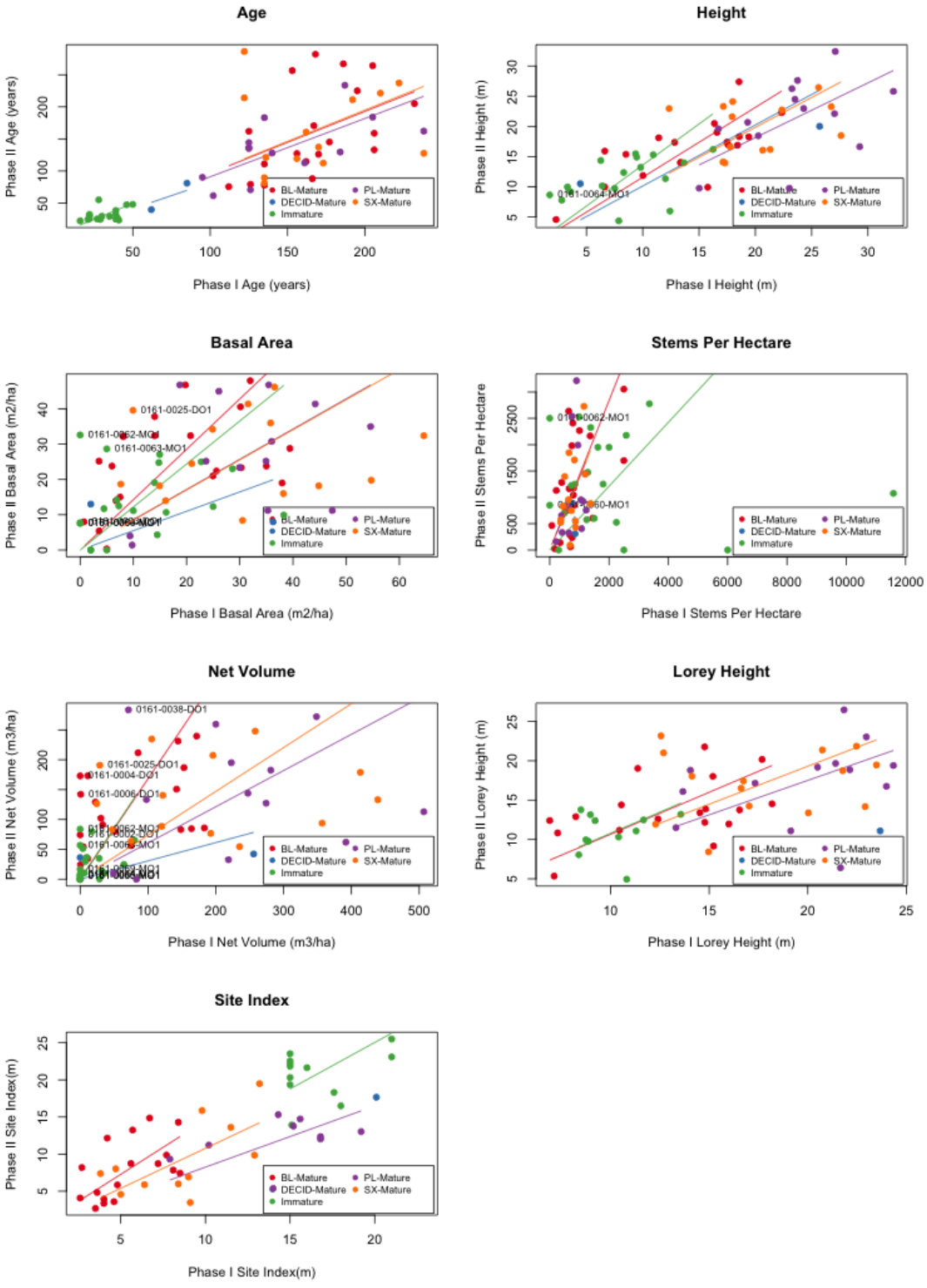

Figure 18: Immature Stratum – Residual Values

APPENDIX VI – SITE INDEX ANALYSIS PROCEDURES

Supplemental procedures and input data were provided for the analysis of site index as described below:

1. A *trees_h* file was provided that contains the site index measurements for each tree in each Phase II plot cluster.

2. Leading species was determined for each Phase II plot cluster using the first species from the spb_cpct field in the 4.0+ cm utilization table.

3. An average site index was calculated for each Phase II plot using the trees matching the plot clusters leading species where *treetype* in ('T','L','X','O') and *si_tree* IS NOT NULL and *si_tree* > 0.

4. Site index for the leading species was taken from the Phase I VRI. SiteTools was used to calculate a site index for the second species using the species 2 age, height and species.

5. The Phase II site index for each plot was matched to the Phase I species 1 site index if the leading species were the same. If the Phase II leading species was the same as the Phase I species 2 then the Phase II site index was matched with the Phase I species 2 site index. If neither matched then the plot and polygon were both dropped from the site index analysis. In all matching, 'S', 'SX', and 'SW' were considered to be matches as were 'PL' and 'PLI'.

6. ROM and sampling error calculations were carried out as described in the procedures and in Section above.

APPENDIX VII – ANALYSIS OF INVENTORY SPECIES

Table 9 presents an assessment of the accuracy of the Phase I leading species with correct values highlighted in green. Overall, if SW / SX / S values are considered matches then leading species is correct 46% of the time.

Table 10 shows the percent distribution of Phase I species composition while Table 11 shows the percent distribution of Phase II species composition.

Table 9: Leading Species Comparison

Phase II Leading Species	Phase I Leading Species					Total	% Correct
	AT	BL	EP	PL	S		
AT	1			1	2	4	25%
BL		15		5	9	29	52%
EP				1		1	0%
PL	2		1	7		10	70%
S	1	6		7	9	23	39%
SB				1		1	0%
(blank)		2				2	0%
Total	**4**	**23**	**1**	**22**	**20**	**70**	46%

Table 10: Leading Species Comparison – Percent Distribution of Phase I Species (Column)

Phase II Leading Species	Phase I Leading Species					Total	Total %
	AT	BL	EP	PL	S		
AT	25%	0%	0%	25%	50%	4	100%
BL	0%	52%	0%	17%	31%	29	100%
EP	0%	0%	0%	100%	0%	1	100%
PL	20%	0%	10%	70%	0%	10	100%
S	4%	26%	0%	30%	39%	23	100%
SB	0%	0%	0%	100%	0%	1	100%
(blank)	0%	100%	0%	0%	0%	2	100%
Total	**4**	**23**	**1**	**22**	**20**	**70**	
Total %	**6%**	**33%**	**1%**	**31%**	**29%**		**100%**

Table 11: Leading Species Comparison – Percent Distribution of Phase II Species (Row)

Phase II Leading Species	Phase I Leading Species					Total	Total %
	AT	BL	EP	PL	S		
AT	25%	0%	0%	5%	10%	4	6%
BL	0%	65%	0%	23%	45%	29	41%
EP	0%	0%	0%	5%	0%	1	1%
PL	50%	0%	100%	32%	0%	10	14%
S	25%	26%	0%	32%	45%	23	33%
SB	0%	0%	0%	5%	0%	1	1%
(blank)	0%	9%	0%	0%	0%	2	3%
Total	**4**	**23**	**1**	**22**	**20**	**70**	
Total %	**100%**	**100%**	**100%**	**100%**	**100%**		**100%**

APPENDIX VIII – SAMPLE SELECTION DOCUMENTS

Mackenzie Timber Supply Area

TSA16

Vegetation Resources Inventory Project Implementation Plan for Ground Sampling and Net Volume Adjustment Factor Sampling

Nona Phillips Forestry Consulting
June 16, 2011

Mackenzie TSA VRI Sample Selection Report

Nona Phillips Forestry Consulting

June, 2011

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