PSP Strategy Project

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Potential Applications of Growth Natural PSPs for MPB-Impact Analyses

Prepared for:
Forest Analysis and Inventory Branch
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EXECUTIVE SUMMARY

This report is part of the Growth Natural Permanent Sample Plots (GN-PSP) Strategy Project. It outlines the application of the GN-PSP data to study post-mountain pine beetle (MPB) attack impacts, including stand development modelling, natural regeneration analysis, tree mortality modelling and updating MPB-area maps. It illustrates some of these applications, where possible, using example GN-PSP data from the MPB study GN-PSPs provided by the Forest Analysis and Inventory Branch (FAIB) (Contact: Rene de Jong). There were a total of 142 MPB-impacted PSPs that were before and after MPB attack. Also discussed are the proposed extra attributes to be collected in the GN-PSPs falling in the MPB-impacted areas.

ACKNOWLEDGEMENTS

I thank the FAIB staff who provided background information on the GN-PSP Program or reviewed an earlier draft of this paper: Rene de Jong, Sam Otukol, and Wenli Xu. Finally, I thank Tamara Brierley for providing the relevant project documents and smoothly managing this Project contract.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS II
LIST OF TABLES III
LIST OF FIGURES III
ABBREVIATIONS AND ACRONYMS V
1. INTRODUCTION 1
2. PRE- AND POST-ATTACK STAND DESCRIPTIONS 1
3. STAND DEVELOPMENT MODELLING 3
4. NATURAL REGENERTION ANALYSIS 7
5. TREE MORTALITY MODELLING 8
6. UPDATING MPB-AREA MAPS 9
7. PROPOSED EXTRA MPB ATTRIBUTES TO MEASURE 9
8. CONCLUSION 10
ANNEX 1: LIST OF THE 142 MPB-IMPACT STUDY PROJECT GN-PSPS 12
ANNEX 2: NATURAL REGENERATION DATA FROM 96 MPB-STUDY PROJECT GN-PSPS 16
ANNEX 3: PRELIMINARY PROCEDURES FOR MEASURING WEATHER CHECKS AND SPIRAL GRAIN 21

LIST OF TABLES

Table 1. Pre- and post-MPB attack means and standard errors (in brackets) for selected stand attributes. DP stands for dead potential (trees with at least 50% sound wood) and DU for dead useless (trees with less than 50% sound wood). 1
Table 2. Analysis of risk factors and probability of tree mortality 9
Table 3. Proposed list of additional attributes in pest/disease damaged PSPs. The attributes are listed in priority 10

LIST OF FIGURES

Figure 1. Pre- and Post-MPB attack density (live trees/ha, including ingrowth). The diagonal arrow line shows the line of correspondence (LoC) between the pre-and post-attack density. Some plots are above the LoC likely due to ingrowth. 2
Figure 2. Pre- and Post-MPB attack total volume (m^3/ha; live trees, including ingrowth). The diagonal arrow line shows the line of correspondence (LoC) between pre- and post-attack total volume. Some plots are above the LoC likely due to ingrowth. 2
Figure 3. Pre- and Post-MPB attack net merchantable volume (m^3/ha; live trees, including ingrowth; 10 cm top diameter limit). The diagonal arrow line shows the line

of correspondence (LoC) between pre- and post-attack merchantable volume. Some plots are above the LoC likely due to ingrowth. 3
Figure 4. Stand total volume development in the IDF pre- and post-MPB attack. The sharp drop in volume after the year 2000 is due to mortality likely mostly from the MPB attack. There was a drop in volume in some plots during the period 1985-1990, possibly also due to MPB. 4
Figure 5. Stand net merchantable volume development in the IDF pre- and post-MPB attack. The sharp drop in volume after the year 2000 is due to mortality likely mostly from the MPB attack. There was a drop in volume in some plots during the period 1985-1990, possibly also due to MPB. 4
Figure 6. Stand density development in the IDF pre- and post-MPB attack. The increase in the density is due to ingrowth, and the sharp drop after the year 2000 is due to mortality likely mostly from the MPB attack. 5
Figure 7. Stand total volume development in the SBS pre- and post-MPB attack. The sharp decrease in volume after the year 2000 is due to mortality likely mostly from the MPB attack. 5
Figure 8. Stand net merchntable volume development in the SBS pre- and post-MPB attack. The sharp decrease in volume after the year 2000 is due to mortality likely mostly from the MPB attack. 6
Figure 9. Stand density development in the SBS pre- and post-MPB attack. The initial increase in the density is due to ingrowth, and the sharp drop after the year 2000 is due to mortality likely mostly from the MPB attack. 6
Figure 10. Natural regeneration following MPB attack. The stem count includes all stems 0.3m-1.29 m tall (Class 0), and >=1.3 m tall – 1.29 cm DBH (Class 1). Vertical bars represente (one) standard error. 7
Figure 11. Natural regeneration following MPB attack by small-tree class. The Class 0 includes all stems 0.3m-1.29 m tall and Class 1 includes all stems >=1.3 m tall – 1.9 cm DBH. Vertical bars represent one standard error. 8

ABBREVIATIONS AND ACRONYMS

BC	British Columbia
EP	Experimental Project
FAIB	Forest Analysis and Inventory Branch
GN-PSP	Growth Natural Permanent Sample Plot
LoC	Line of Correspondence
MPB	Mountain Pine Beetle
PSP	Permanent Sample Plot
TASS	Tree and Stand Simulator model
TSR	Timer Supply Review
VDYP7	Variable Density Yield Prediction System
VRI	Vegetation Resources Inventory

1. INTRODUCTION

This report outlines some potential applications of the growth natural permanent sample plot (GN-PSP) data, for pre- and post-mountain pine beetle (MPB) impact analyses, including stand development and natural regeneration. It illustrates some of the applications, where possible, using example GN-PSP data.

The data used for illustration were a part of the MPB study PSPs. They were provided by the Forest Analysis and Inventory Branch (FAIB; Contact: Rene de Jong). There were a total of 142 MPB-impacted GN-PSPs that were re-measured in 2012 and 2013 (Annex 1). They were a part of a larger MPB impact study. The applications discussed include pre- and post-attack stand descriptions, stand development modeling, regeneration analysis, tree mortality modeling, and MPB-area maps update. Also discussed are the extra attributes proposed to be collected in the GN-PSPs falling in the MPB areas.

2. PRE- AND POST-ATTACK STAND DESCRIPTIONS

A sub-set of 23 PSPs from the 142 PSPs was selected to illustrate use of PSP data to study selected pre- and post-attack stand attributes. The criteria for the selection were that the PSPs were established during the period 1997-2000 and remeasured during the period 2012-2013. These plots varied in terms of stand attributes descriptions, such as pre-MPB Pl % composition and stand age. Pre- and post- MPB attack stand attributes statistics (means and standard errors) were calculated (Table 1); and individual plot summaries were graphed (Figures 1 to 3). The selected attributes were stand density, total (whole stem) volume and net merchantable (to a 10-cm top diameter limit) volume of live trees (including ingrowth), dead potential trees (DP; trees with at least 50% sound wood) and dead useless trees (DU; trees with less than 50% sound wood).

As expected, there was a drop in the magnitude of all the live-tree attributes, and an increase in the amount of dead material, after the MPB attack. These tables and figures can be used to explain to forest managers and practitioners the impact of MPB attack on stand attributes.

Table 1. Pre- and post-MPB attack means and standard errors (in brackets) for selected stand attributes. DP stands for dead potential (trees with at least 50% sound wood) and DU for dead useless (trees with less than 50% sound wood).

MPB attack	Density (trees/ha)			Total Volume (m^3/ha)			Net Merch. Volume (m^3/ha)		
	DU	DP	Live	DU	DP	Live	DU	DP	Live
Pre-MPB	45 (6)	9 (16)	2568 (388)	5.4 (0.9)	1.3 (2.6)	214.1 (28.4)	0.9 (0.6)	2.0 (1.1)	134.0 (22.9)
Post-MPB	485 (70)	245 (93)	2395 (415)	118.2 (11.9)	18.1 (24.6)	130.4 (17.7)	5.6 (4.2)	45.1 (10.4)	64.3 (12.7)

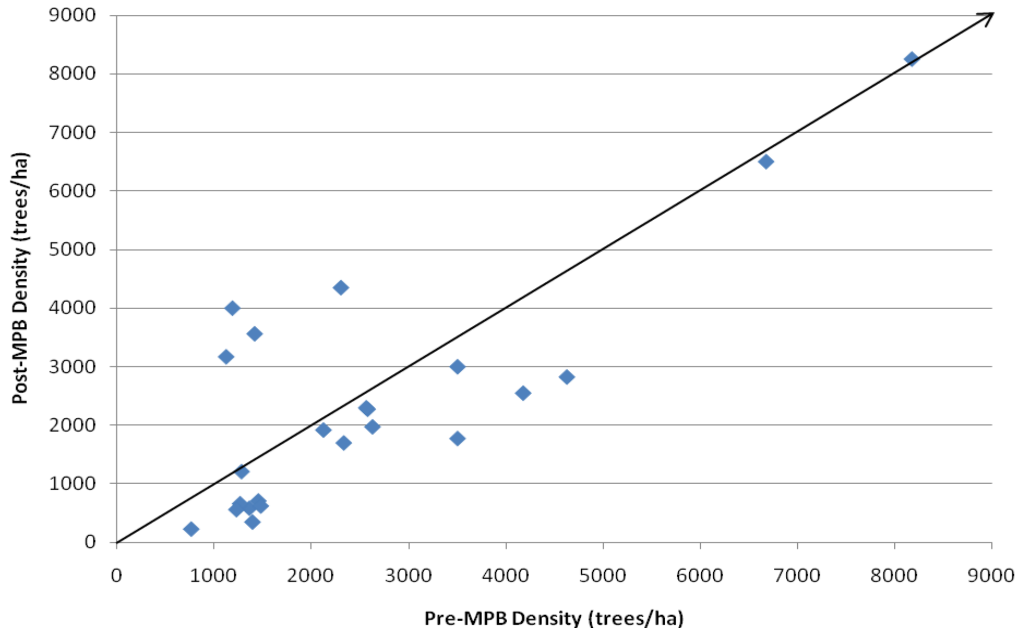

Figure 1. Pre- and Post-MPB attack density (live trees/ha, including ingrowth). The diagonal arrow line shows the line of correspondence (LoC) between the pre-and post-attack density. Some plots are above the LoC likely due to ingrowth.

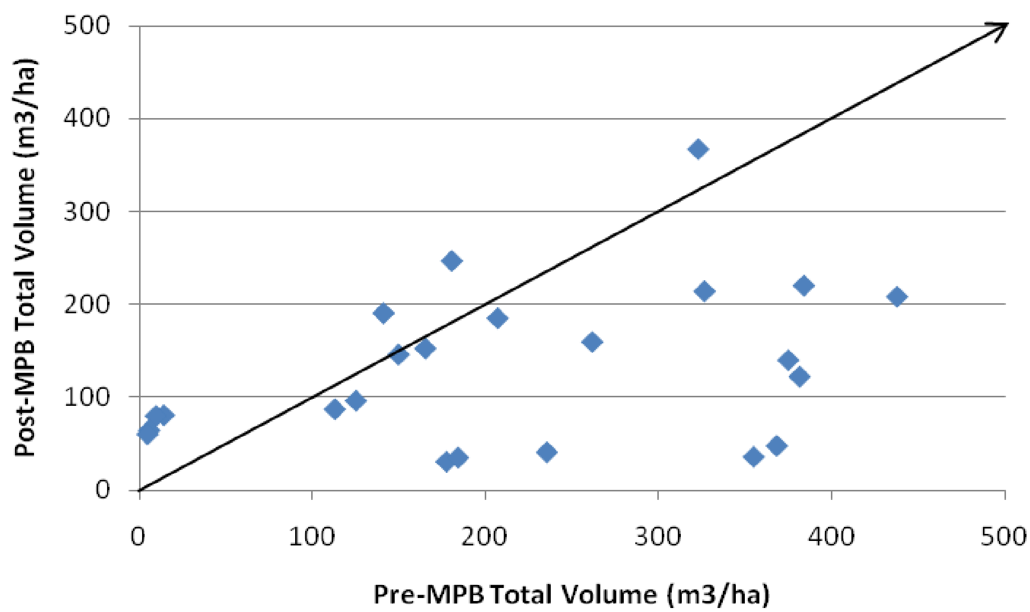

Figure 2. Pre- and Post-MPB attack total volume (m^3/ha; live trees, including ingrowth). The diagonal arrow line shows the line of correspondence (LoC) between pre- and post-attack total volume. Some plots are above the LoC likely due to ingrowth.

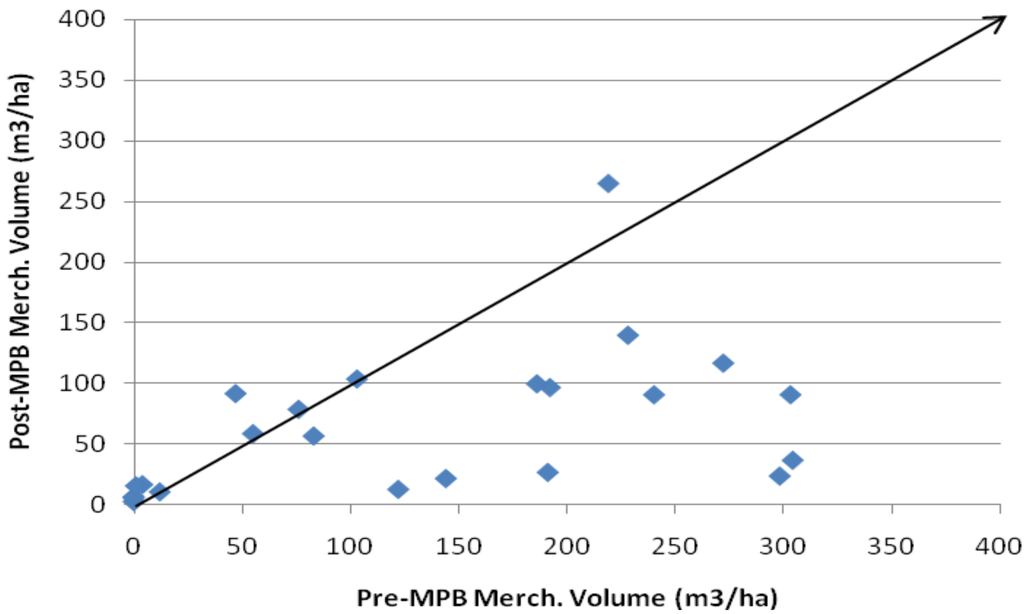

Figure 3. Pre- and Post-MPB attack net merchantable volume (m^3/ha; live trees, including ingrowth; 10 cm top diameter limit). The diagonal arrow line shows the line of correspondence (LoC) between pre- and post-attack merchantable volume. Some plots are above the LoC likely due to ingrowth.

3. STAND DEVELOPMENT MODELLING

Stand development, in terms of stand density, total volume and net merchantable volume, was studied in the IDF and SBS zones using a sub-sample of GN-PSPs with five or more measurements. These two zones each had a reasonable number of PSPs (9 and 11, respectively). Individual plot development was graphed over time, and the trends examined.

The results clearly show the sharp drop in stand density and total and net merchantable volume following the MPB attacks (Figures 4 to 9). Thus, the PSPs could be used study stand development, similar to the work done by Amoroso, *et al*. (2013),[1] who used dendrochronological techniques. These stand development trends can be used to re-calibrate (define the upper limit of the prediction space of MPB-damaged stands) for models such as TASS and VDYP7, to account for the excessive mortality due to MPB.

[1] Amoroso, M.M., K.D. Coates and R. Astrup. 2013. Stand recovery and self-organization following large-scale mountain pine beetle induced canopy mortality in northern forests. For. Ecology and Manage. 310: 300-311.

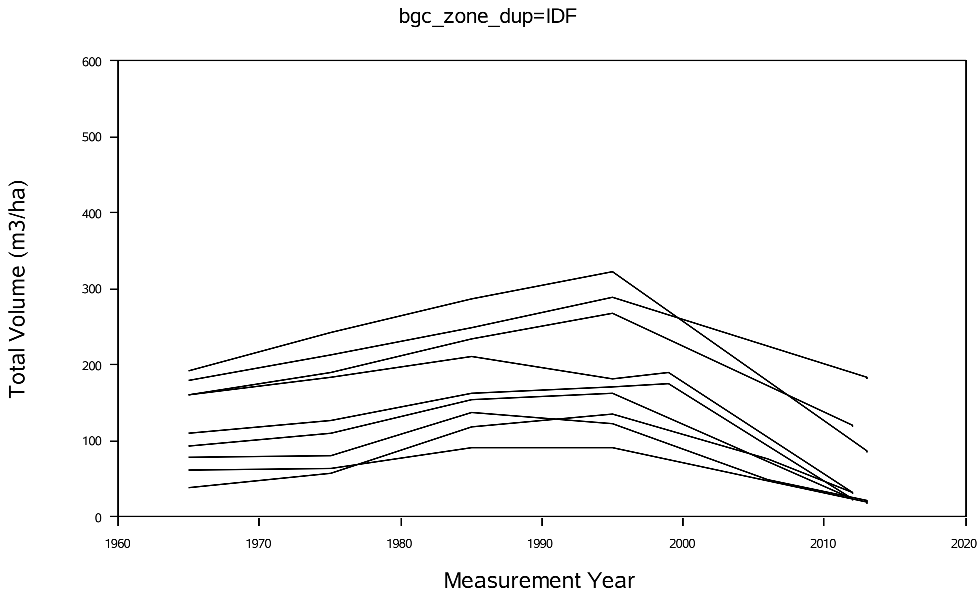

Figure 4. Stand total volume development in the IDF pre- and post-MPB attack. The sharp drop in volume after the year 2000 is due to mortality likely mostly from the MPB attack. There was a drop in volume in some plots during the period 1985-1990, possibly also due to MPB.

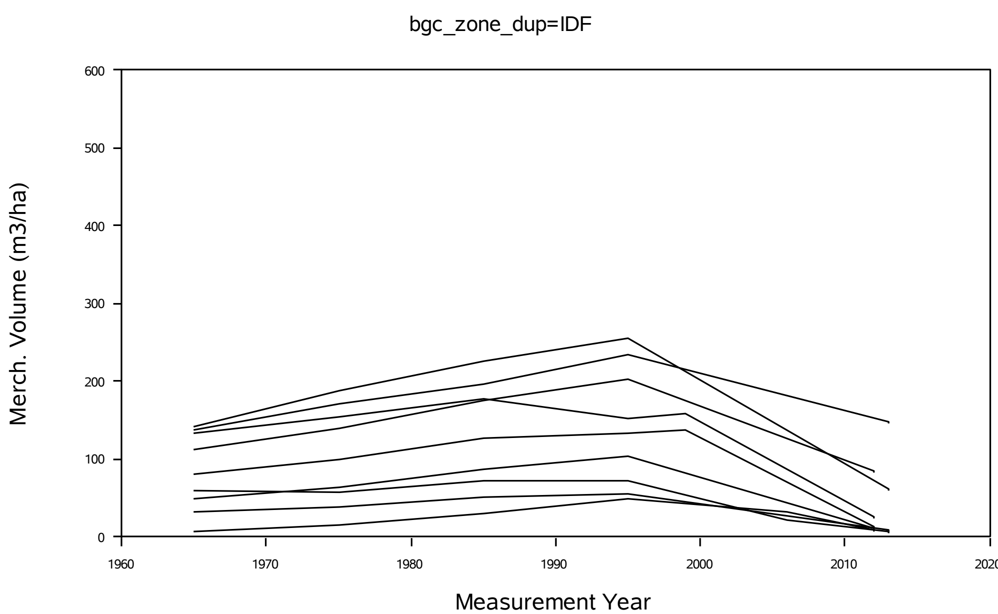

Figure 5. Stand net merchantable volume development in the IDF pre- and post-MPB attack. The sharp drop in volume after the year 2000 is due to mortality likely mostly from the MPB attack. There was a drop in volume in some plots during the period 1985-1990, possibly also due to MPB.

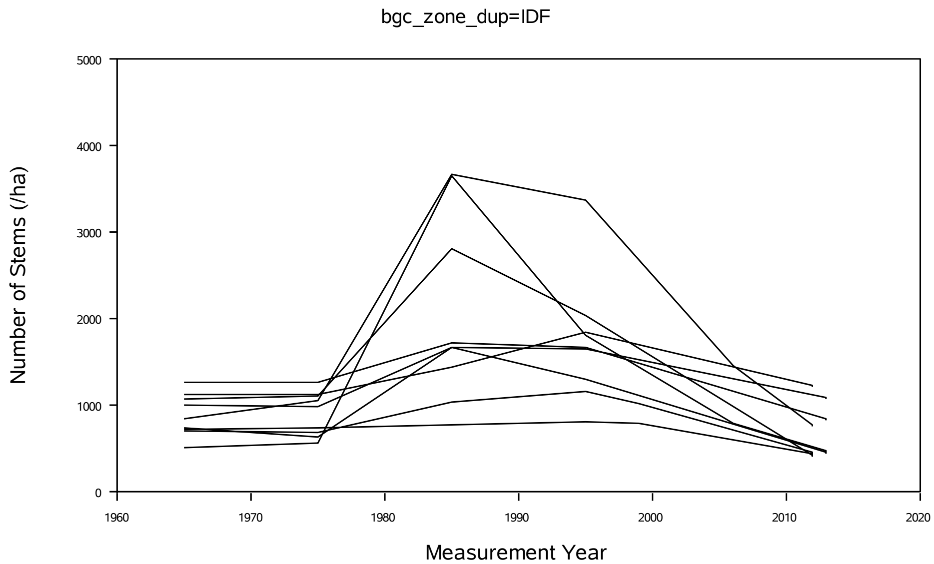

Figure 6. Stand density development in the IDF pre- and post-MPB attack. The increase in the density is due to ingrowth, and the sharp drop after the year 2000 is due to mortality likely mostly from the MPB attack.

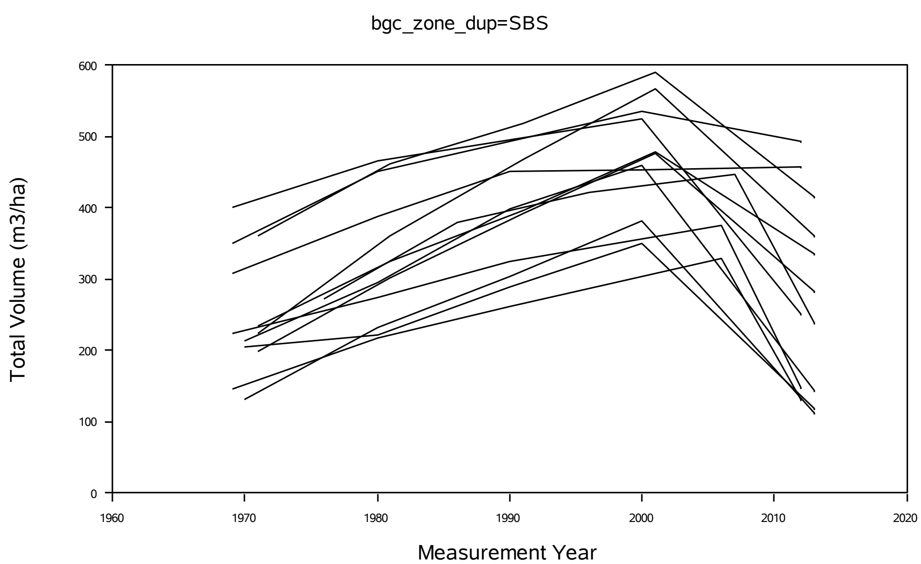

Figure 7. Stand total volume development in the SBS pre- and post-MPB attack. The sharp decrease in volume after the year 2000 is due to mortality likely mostly from the MPB attack.

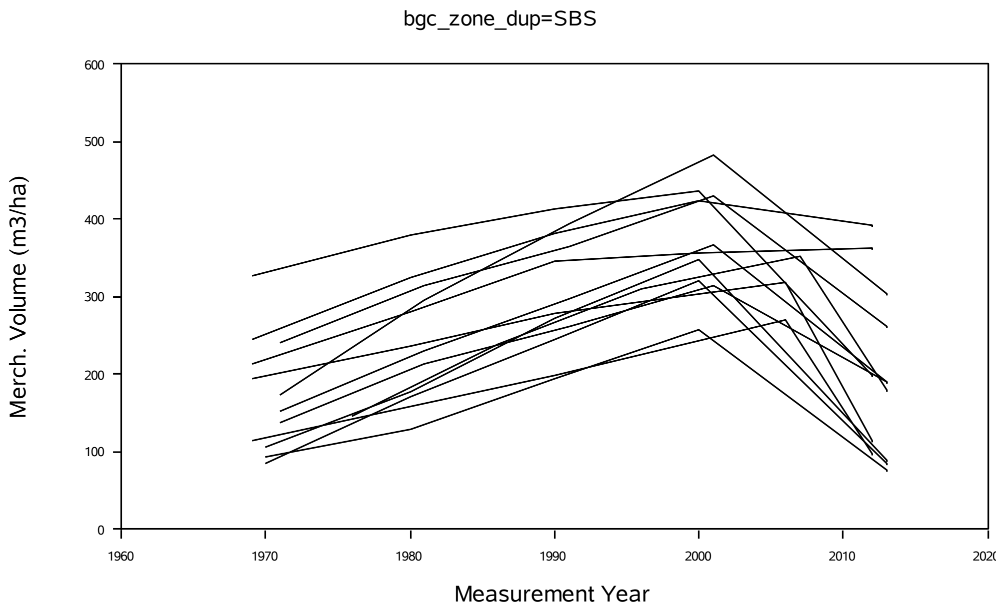

Figure 8. Stand net merchantable volume development in the SBS pre- and post-MPB attack. The sharp decrease in volume after the year 2000 is due to mortality likely mostly from the MPB attack.

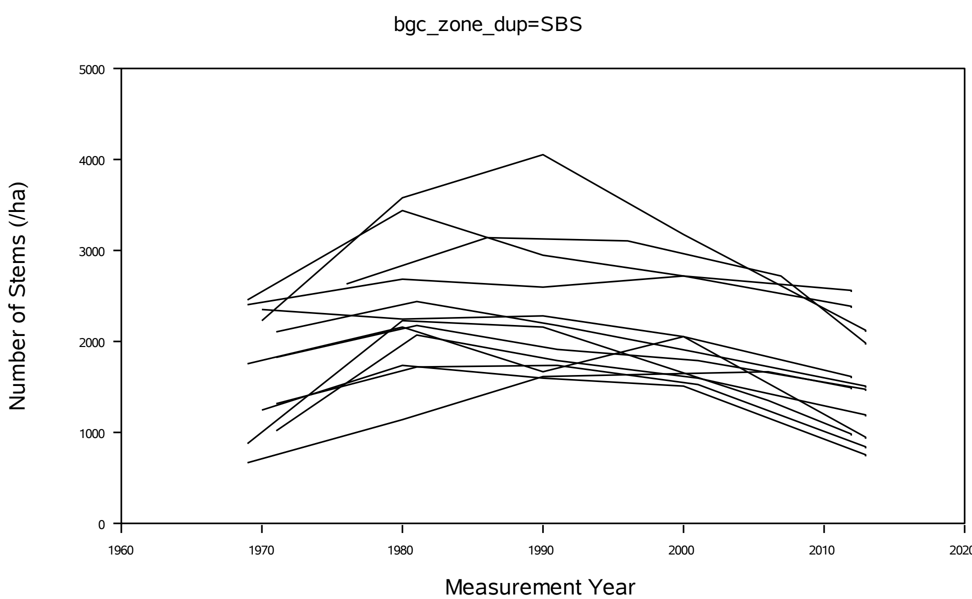

Figure 9. Stand density development in the SBS pre- and post-MPB attack. The initial increase in the density is due to ingrowth, and the sharp drop after the year 2000 is due to mortality likely mostly from the MPB attack.

4. NATURAL REGENERTION ANALYSIS

Out of the 142 study PSPs, 96 had natural regeneration (NR) following the MPB attack (Annex 2). Natural regeneration data collected in 2012-2013 included tallies of small-tree stems in sub-plots in two classes: Class_0 (stems 0.3 m-1.29 m tall) and Class_1 (stems > 1.29 cm DBH & < 1.9 cm DBH). The sub-plot sizes varied among the PSPs. To illustrate natural regeneration analysis, descriptive statistics of the stem counts were calculated by species and small-tree classes from the NR data from the 96 PSPs.

For this example data set, most of the natural regeneration consisted of Cw, Sw and Bl species (Figure 10), and most of the regeneration was concentrated in the stems 0.3 m-1.29 m tall (Figure 11). Knowledge of information like this could contribute to TASS re-calibration efforts or use of TIPSY in timber supply review.

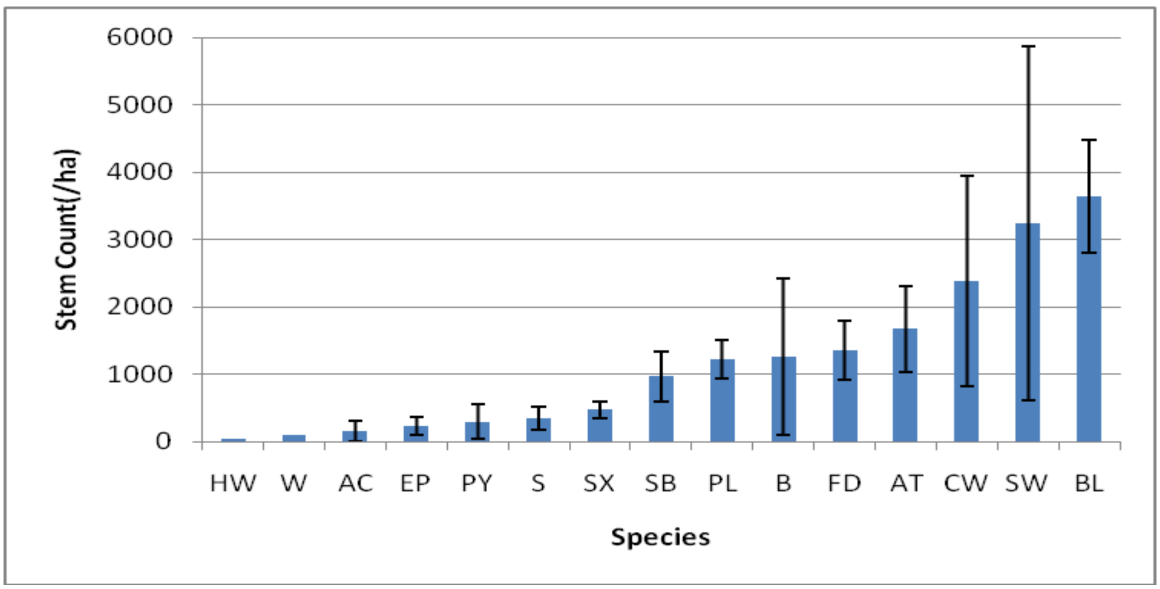

Figure 10. Natural regeneration following MPB attack. The stem count includes all stems 0.3m-1.29 m tall (Class 0), and >=1.3 m tall – 1.29 cm DBH (Class 1). Vertical bars represent (one) standard error.

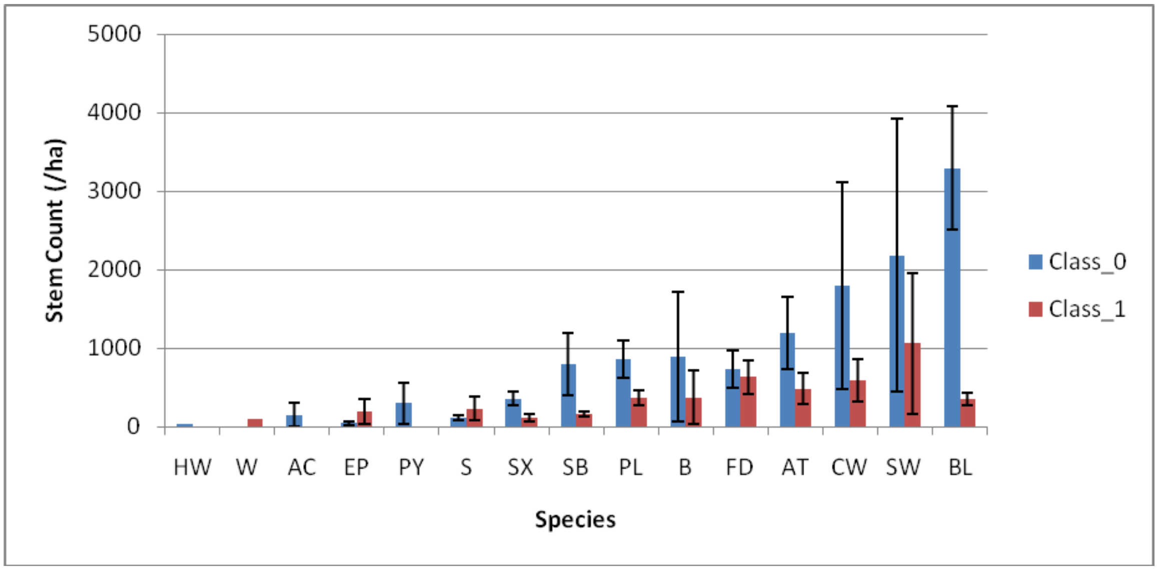

Figure 11. Natural regeneration following MPB attack by small-tree class. The Class 0 includes all stems 0.3m-1.29 m tall and Class 1 includes all stems >=1.3 m tall – 1.9 cm DBH. Vertical bars represent one standard error.

5. TREE MORTALITY MODELLING

Tree mortality modeling has been done by several researchers. For example, Lee, et al. (undated)[2] used experimental plot (EP) data to jointly model tree growth and mortality in coastal BC. They could have used the GN-PSPs as well, since some of these have longer remeasurement periods than the EP data they used.

We illustrate how to use the MPB-impacted PSP data to model the risk factors (past tree pathological measurements) that may be related to tree mortality. This is based on the work done by Omule (2007).[3] The data used in this study consisted of individual-tree remeasurements at Time 1 and Time 2, which correspond to pre-MPB and post-MPB measurements, respectively, from the 142 PSP MPB study data provided by FAIB. Only the lodgepole trees were used in this exploratory analysis; there were a total of 8,180 lodgepole pine trees alive at Time 1.

The pathological factors investigated were: broken top (BRKNTOP), mistletoe (MISTLE), frost-crack (FROST), scar (SCAR), fork/crook (FKCROOK), conk (CONK), dead top (DTOP) and blind conk (BL_CONK). Only the presence/absence of these pathological attributes was investigated; the location of the defect on the tree bole was not.

None of the factors examined were statistically significant (95% probability), except for dead top (DTOP) (Table 2; Wald chi-square). This suggests that, for this example dataset,

[2] Lee, T.C.K., C.B. Dean, L. Zeng, R. Parish, I. Cameron, and J.W. Goudie. (Undated). Joint modeling of tree growth and mortality using data from permanent sample plots in coastal British Columbia. Draft report.
[3] Omule, A.Y. 2007. Exploratory statistical analysis of dead tree data from inventory growth & yield permanent sample plots. Contract report to FAIB, Victoria, BC.

past presence of fork/crook, mistletoe, broken top and insect/disease damage were not important risk factors affecting tree mortality. However, these results may be confounded by several factors, including tree age, and the short observation period (approximately 10 years).

Table 2. Analysis of risk factors and probability of tree mortality

Analysis of Maximum Likelihood Parameter Estimates (GENMOD output)

Parameter		DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept		1	-1.9121	0.5942	10.36	0.0013
SCAR	0	1	-0.0119	0.0557	0.05	0.8310
SCAR	1	0	0.0000	0.0000	.	.
FKCROOK	0	1	-0.0392	0.0515	0.58	0.4456
FKCROOK	1	0	0.0000	0.0000	.	.
FROST	0	1	0.0106	0.4745	0.00	0.9822
FROST	1	0	0.0000	0.0000	.	.
MISTLE	0	1	0.5044	0.3467	2.12	0.1457
MISTLE	1	0	0.0000	0.0000	.	.
DTOP	0	1	-0.7820	0.0925	71.42	<.0001

6. UPDATING MPB-AREA MAPS

The recent re-measurement data from GN-PSPs are normally considered as potential data sources for VRI Phase I photo-interpretation (Data Source Code 19), to aid in estimating stand species composition, age and height.[4] These data, however, cannot be used for VRI statistical adjustment because the PSPs are subjectively located. Applications should be explored for using, not only the recent measurements, but also the past measurements in the photo interpretation. For, example, the GN-PSP data could be used to check the polygon history data, such as past pest damage and year of infestation.

7. PROPOSED EXTRA MPB ATTRIBUTES TO MEASURE

Several attributes have been proposed to be collected in PSPs that are pest damaged (including MPB areas), with residual basal area more than 5%, or more than five trees killed by beetles, defoliators or root rot. These additional attributes, which were proposed by K. Hardy of FAIB, are given in Table 1:[5]

[4] MFLNRO FAIB. 2012. Vegetation Resources Inventory Photo Interpretation Procedures. Version 2.8. Victoria, BC.
[5] Information provided by Kevin Hardy of FAIB, dated September, 2014.

Table 3. Proposed list of additional attributes in pest/disease damaged PSPs. The attributes are listed in priority.

Attribute	*Description*
1.	Stem mapping of either live trees dbh > 4 cm or dead trees > 10 cm dbh, whichever is less effort.
2.	Heights on all dead standing plot trees killed by Beetle or Defoliator or Root Rot.
3.	Heights on all suitable live plot trees to nearest 0.1 m.
4.	Heights to Live crown on Live Height trees.

This list of proposed attributes (Table 3) is reasonable, except for the stem mapping (Attribute 1) and heights of live trees (Attribute 3). For the stem maps to be most useful, both live and dead trees must be stem mapped. For tree heights, there should be a clear explanation of what "suitable live plot trees" means, and an evaluation of the additional cost of measuring heights of more trees.

Data on wood quality should also be considered, to enable quantification of shelf life in the MPB-attack areas. The tree attributes suggested by Bob Macdonald, namely, length of weather checks and spiral grain displacement, should be tested again, possibly on a sample of trees, before implementation. Further details of these procedures for measuring weather checks and spiral grain are given in Annex 3 (copied from the report by Omule (2007)).[2]

Stone, et al (2002)[6] recommend continued collection of data on standing dead-tree dynamics – track dead standing trees until they are dead fallen. This should be done in the MPB-attack areas, if it is not already being done. These data can be used, for example, for modeling the probability of a dead standing tree of a given diameter becoming dead fallen in the future. These models have been integrated into GY models such as TASS, to help understand characteristics of wildlife patches, as well as safety concerns.

8. CONCLUSION

This report has demonstrated potential applications of the GN-PSPs for MPB-related analyses. The applications discussed include stand development modeling, natural regeneration analysis, modeling tree mortality, and updating MPB-area maps. Also discussed are the proposed extra attributes to be collected in the GN-PSPs falling in the MPB areas. The data used for illustration were from the MPB study GN-PSPs provided by the Forest Analysis and Inventory Branch (FAIB) (Contact: Rene de Jong). There were a total of 142 MPB-impacted PSPs that were re-measured in 2012 and 2013, a part of a

[6] Stone, J, J. Parminter, and J. Braz. 2002. Standing dead tree dynamics extracted from growth and yield permanent sample plots in British Columbia. USDA Forest Service, Gen. Tech. Rep. PSW-GTR-181.

larger MPB impact study. The overall concussion is that the GN_PSP data are useful in describing pre-and post-MPB attacked stand status, and modeling natural regeneration, stand development and tree mortality in MPB areas, and other uses. Remeasurement of these MPB-impacted PSPs should be continued.

ANNEX 1: LIST OF THE 142 MPB-IMPACT STUDY PROJECT GN-PSPs

The list of the subset of 142 MPB-impacted study plots is shown in the table below, along with plot level attributes. The site index, total age and top height are for the leading species; Dbhq is quadratic mean DBH, WSV is whole stem volume, NMV10 is net merchantable volume to a 10-cm top (net decay). These data were a part of a larger MPB impact study provided by the Forest Analysis and Inventory Branch (FAIB) (Contact: Rene de Jong).

PSP Sample ID	*BGC zone*	*Yr est.*	*Dbhq (cm)*	*Stems/ha*	*WSV/ha (m3/ha)*	*NMV10/ha (m3/ha)*	*Species composition (% by basal area)*	*Site Index (m)*	*Total Age (yrs)*	*Top height (m)*
25021 G000004	IDF	1972	16.1	2260	331	248	PL73FD24SE2BL1	24	38	18
34001 G000006	IDF	1972	22.1	445	100	82	FD65PY35	16	77	19
35001 G000001	PP	1993	18.7	980	169	141	PY97FD2JR1	10	127	19
47007 G000001	IDF	1977	18.0	484	80	60	FD64PL34AT2	14	86	17
47009 G000002	SBPS	1991	5.3	2800	15	0	PL100	20	10	6
47013 G000003	IDF	1994	26.3	850	458	246	AT99FDI1W0	16	114	25
47013 G000004	IDF	1994	22.1	760	300	176	AT87PL10AC2W1SX1FD0	19	98	26
47017 G000007	IDF	1992	13.5	2120	246	194	FD100PL0	15	181	27
47026 G000003	IDF	1965	16.4	1273	193	143	PL90FD9SX1	13	105	18
47026 G000007	IDF	1965	15.0	1137	160	112	PL96FD4	16	72	18
47026 G000008	IDF	1965	17.7	1001	179	139	PL53FD47	18	65	19
47029 G000001	IDF	1965	18.9	733	161	133	PL99FD1	16	64	18
47029 G000002	IDF	1965	16.4	713	109	81	PL100	15	73	18
47030 G000001	IDF	1965	13.2	741	62	33	PL100	13	82	16
47030 G000002	IDF	1965	16.7	512	78	59	PL100	13	86	16
47030 G000007	IDF	1965	10.9	847	40	7	PL100	11	129	14
47030 G000008	IDF	1965	13.3	1077	94	48	PL100	14	80	16
47057 G000002	IDF	1991	11.1	1650	52	17	FD71PY29AT0	15	44	12
47057 G000003	IDF	1991	10.5	3000	88	33	FD57PY42AT1	13	60	13
47059 G000001	IDF	1991	9.4	1634	46	27	FD66PL34	11	82	13
47059 G000002	IDF	1991	6.8	1840	18	0	PL98FD1AT1	-99	21	7
48011 G000001	MS	1998	10.2	3500	150	55	PL100	10	79	13
48011 G000002	MS	1998	8.5	6675	180	47	PL100	11	62	11
48011 G000003	MS	1998	7.5	8175	141	4	PL100	8	72	10
48012 G000002	IDF	1992	6.8	1033	9	1	FD88PL12W1	14	55	8
48013 G000003	MS	1998	5.4	1184	5	0	PL100	14	18	4
48013 G000004	MS	1998	26.1	760	368	304	PL98S2	13	186	22
48013 G000005	MS	1998	5.2	1120	5	0	PL100	13	17	4
48013 G000006	MS	1998	20.1	1450	382	304	PL92BL5S3	10	203	19
48014 G000002	MS	1998	5.9	2300	14	0	PL100	15	29	5
48014 G000004	MS	1998	12.9	4175	384	192	PL100	8	230	17
48014 G000005	MS	1998	14.3	3500	438	272	PL94SX6	8	202	16

PSP Sample ID	*BGC zone*	*Yr est.*	*Dbhq (cm)*	*Stems/ha*	*WSV/ha (m3/ha)*	*NMV10/ha (m3/ha)*	*Species composition (% by basal area)*	*Site Index (m)*	*Total Age (yrs)*	*Top height (m)*
48014 G000006	SBPS	1998	15.3	2575	327	228	SX74PL26	6	219	20
48018 G000001	MS	1998	6.1	1413	9	1	PL82S17BL1	-99	19	5
48058 G000001	IDF	1991	12.6	2084	176	111	PL93FD4SB3	16	69	19
48059 G000005	IDF	1993	8.8	425	8	3	FD56PL31AT14	13	77	10
48060 G000005	IDF	1995	12.4	1238	74	47	FD48PL44AT8W0	15	60	14
48060 G000006	IDF	1995	7.8	7850	179	53	PL59FD39AT2	14	70	16
48089 G000002	SBPS		12.1	433	29	20	PL100	7	260	14
48089 G000008	SBPS		9.9	1811	76	25	PL100	4	231	10
48089 G000011	SBPS		16.9	356	64	48	PL100	11	134	18
48089 G000016	MS		16.9	878	149	111	PL100	9	223	18
48089 G000017	MS		18.4	211	51	41	PL100	13	227	21
55002 G000001	SBS	1995	7.4	4775	109	1	AT91W5SW2EP1FD0PL0	27	47	17
55013 G000001	SBPS	1995	12.3	3325	319	181	PL67SB33	16	95	21
55013 G000003	SBPS	1995	10.7	1850	97	41	PL90S7AT3	18	29	12
55015 G000001	SBS	1995	6.7	3450	36	1	BL82PL14SW4	18	26	7
55017 G000002	SBPS	1995	13.7	1270	141	108	PL72S24AT4	17	69	19
55018 G000013	SBPS	1970	11.0	1088	68	14	PL100	16	44	13
55018 G000024	SBS	1970	12.9	2237	213	105	PL99S1	21	40	16
55018 G000026	SBS	1970	12.6	2361	204	93	PL99S1	17	55	16
55018 G000034	SBS	1970	14.5	1261	131	85	PL100	21	33	14
55018 G000048	SBPS	1995	9.8	4025	162	67	SB79PL21	8	154	14
55020 G000001	SBS	1994	8.9	3000	93	16	PL93SB7SW0	20	31	11
55025 G000043	SBS	1994	17.3	1415	230	183	FD53PL47EP0	15	72	18
55026 G000003	SBPS	1995	7.0	1543	19	0	PL77BL21SW3	19	20	7
55026 G000004	SBPS	1995	9.7	4575	285	76	PL100	14	73	17
55030 G000002	SBPS	1993	9.6	4450	182	97	SB60PL40	9	87	11
55032 G000001	SBPS	1994	6.0	2450	21	0	PL99AC1	22	14	6
55033 G000001	SBPS	1993	8.0	7800	250	29	PL100	14	57	14
55056 G000001	SBPS	1994	13.0	1313	90	30	AT92W7PL1	13	79	15
55061 G000001	SBPS	1995	13.8	2140	242	134	AT54PL32SW9SB4	12	89	17
55061 G000002	SBPS	1995	9.1	4700	191	66	PL69SB31	14	65	16
55095 G000001	SBPS	1993	8.8	4850	174	28	PL100	9	88	13
56019 G000002	SBS	1993	16.2	2380	390	293	S65BL26FD5AT3CW1	16	74	20
56019 G000003	SBS	1995	8.2	4150	115	11	PL100FD0W0	22	25	12
56019 G000004	SBS	1995	11.2	2900	158	72	AT40PL39SW10AC5BL2EP2	22	27	14
56023 G000003	SBS	1993	5.7	1960	15	0	PL85AT9BL4SW2	22	15	6
56023 G000005	SBS	1993	6.4	2800	29	2	PL75BL10FD10S3EP1W1	21	17	7
56023 G000007	SBS	1995	5.6	3450	25	0	PL97SW3FD1	22	15	6
56049 G000054	ICH	1997	15.5	2120	323	218	AT33S24CW19BL12HW8FD4	20	93	26
56052 G000001	SBS	1991	8.3	2000	46	5	PL98AT1W1	23	23	9

PSP Sample ID	*BGC zone*	*Yr est.*	*Dbhq (cm)*	*Stems/ha*	*WSV/ha (m3/ha)*	*NMV10/ha (m3/ha)*	*Species composition (% by basal area)*	*Site Index (m)*	*Total Age (yrs)*	*Top height (m)*
56052 G000002	SBS	1996	4.7	1300	6	0	PL100	21	12	4
56053 G000100	SBS	1993	26.9	990	653	570	FD60PL34S4EP1	19	149	32
56054 G000006	SBS	1994	16.8	1634	253	165	AT47PL23SX22FD8	-99	57	18
56055 G000005	SBPS	1994	11.9	2825	285	163	PL98SX2	16	73	19
56055 G000006	SBS	1994	18.1	1330	293	236	PL54SX37AT6FD3W0	17	112	22
56055AG000008	ESSF	1994	7.8	1684	23	1	B63SX35AC1BL1	18	26	6
56057 G000002	ICH	1992	8.0	4325	106	4	PL96FD2CW1W1	17	31	11
56066 G000002	ICH	1992	8.9	4200	103	23	CW80HW6W6SE5AT2BL1	18	33	10
56067 G000002	ESSF	1993	12.7	3875	318	220	BL67S18PL15AT0	13	85	18
56069 G000001	SBS	1995	11.0	1880	107	56	PL58SW36FD5W1	20	30	14
56069 G000002	SBS	1991	8.9	2475	55	14	FD64PL19W11AC4AT3	23	49	11
57016 G000002	SBS	1994	19.1	1313	320	244	AT31PL31FD20SX17W1EP0	18	70	20
57017 G000008	SBPS	1994	6.7	2280	29	1	PL74AT26	23	21	8
57017 G000009	SBPS	1994	9.1	2975	108	33	PL78AT22	21	31	14
57017 G000010	SBPS	1994	7.5	4300	88	16	AT67PL33	15	37	10
57018 G000004	ICH	1993	16.4	1643	292	237	PL68S20FD11BL1W0	22	55	22
57018 G000006	ICH	1994	19.5	1772	545	452	FD47PL31EP12SX4AT4B1	20	96	27
60056 G000002	SBS	1991	7.3	7500	171	5	PL100SW0	16	46	14
60061 G000001	SBS	1992	8.5	2700	64	5	PL97SW3BL1	19	23	9
60070 G000001	SBS	1992	9.2	4050	109	22	PL64SW31BL5	19	28	10
60082 G000025	SBS	1993	18.5	1550	371	312	SW68PL28BL4	16	106	25
60114 G000002	SBS	1992	6.6	3425	35	0	BL66PL34	17	31	7
60132 G000038	SBS	1993	13.8	1525	168	128	PL86AT8W6	18	58	18
60136 G000003	SBS	1970	18.3	877	146	113	PL82BL12S6	17	50	16
60136 G000004	SBS	1970	24.1	667	224	195	PL100	16	67	18
60136 G000062	SBS	1993	16.8	2067	422	347	PL82SW12BL7	16	125	23
60136 G000063	SBS	1993	19.5	1850	519	437	PL61SW35BL4	18	122	25
60136 G000064	SBS	1993	18.7	1980	499	407	PL57BL38SW4	17	120	25
60137 G000029	SBS	1993	18.8	2134	509	407	BL52PL27SW20DR1	12	142	23
60148 G000023	SBS	1993	14.6	2434	325	265	PL55SW23BL22	18	87	22
60150 G000004	SBS	1970	15.2	2411	309	214	PL100	16	62	17
60150 G000007	SBS	1970	18.6	1759	400	327	PL99S0BL0	16	73	19
60150 G000009	SBS	1970	15.9	2470	350	245	PL92SW8BL1	15	69	17
60174 G000002	SBS	1994	12.0	3775	286	184	PL60SW40	20	52	18
66004 G000023	SBS	1992	13.3	3925	454	271	PL100	17	73	19
66004 G000024	SBS	1992	22.3	980	319	282	PL88SW12DR0BL0	21	60	21
66004 G000025	SBS	1992	13.0	2800	244	163	BL84SW16	14	92	19
66004 G000027	SBS	1992	11.2	4100	324	169	PL79SW12SB9W0	22	51	21
66006 G000012	SBS	1992	8.6	6525	194	20	PL100	15	43	12
66014 G000116	SBS	1992	15.5	1675	197	151	PL50SW35BL15	17	58	17

PSP Sample ID	*BGC zone*	*Yr est.*	*Dbhq (cm)*	*Stems/ha*	*WSV/ha (m3/ha)*	*NMV10/ha (m3/ha)*	*Species composition (% by basal area)*	*Site Index (m)*	*Total Age (yrs)*	*Top height (m)*
66014 G000117	SBS	1992	18.4	1786	418	333	PL62BL29SW10	-99	171	-99
66014 G000120	SBS	1992	7.9	7275	196	47	PL82SB18	12	64	13
66014 G000127	SBS	1992	26.3	700	398	341	PL70SW30W0	20	113	27
66014 G000128	SBS	1992	25.6	670	360	311	PL64SW35W1BL0	19	115	26
66022 G000045	SBS	1992	15.2	3400	602	453	PL92BL5SW3	16	118	23
67008 G000043	SBS	1993	12.5	3225	240	153	SW43PL28BL22W7DR1	14	66	15
67023 G000051	SBS	1993	13.5	860	76	53	PL100	12	95	15
67024 G000127	SBS	1993	23.1	1167	566	497	SW72BL15PL13	22	104	32
67024 G000128	SBS	1993	17.8	1263	221	179	SW70W12BL10PL8	17	68	19
68059 G000001	SBS	1994	13.1	2060	181	117	PL68SW30BL2W0	18	48	15
69009 G000001	SBS	2000	8.1	4625	125	12	PL89SB11	13	57	13
69018 G000001	SBS	1976	16.8	1483	223	162	AT43PL35SW16BL6	21	38	19
69018 G000010	SBS	1976	13.4	2694	268	145	PL100	18	49	16
69018 G000011	SBS	1976	14.3	2212	277	175	PL100	19	48	17
69018 G000013	SBS	1976	14.9	1956	196	126	BL40PL37SW20AT4	16	54	14
69018 G000017	ESSF	2000	18.6	1358	355	298	PL97SW2BL1	16	112	22
69018 G000018	SBS	2000	14.9	2329	262	186	PL31BL31SW26AT11SB0	17	66	19
69019 G000002	SBS	1976	17.0	909	123	88	PL57AT28SW15	17	48	16
69019 G000009	SBS	2000	11.3	2560	165	77	PL93SB7	13	72	15
69022 G000007	SBS	1976	13.3	2643	273	146	PL100	20	45	17
69022 G000015	ESSF	2000	12.4	2625	207	104	PL100	14	67	16
69022 G000016	ESSF	2000	14.5	1278	113	84	PL72SW17BL11	16	51	14
69022 G000018	SBS	2000	16.4	1263	235	191	PL92SW8BL0	14	120	21
69049 G000002	SBS	2000	13.8	1475	177	122	PL94SB3SW2W1AT0BL0	18	64	19
69053 G000014	ESSF	1998	21.2	1390	375	241	AT68SE14BL11PL4DM2W1	14	107	21
69062 G000001	SBS	1971	17.4	1018	199	153	PL49AT37EP14	25	41	20
69062 G000002	SBS	1971	14.3	1828	234	138	AT65PL32EP3	22	42	20
69062 G000005	SBS	1971	17.7	1324	224	174	PL35BL29SW19EP12AT4	22	39	16
69099 G000006	ESSF	2000	16.7	1225	184	144	PL89BL8SW1AT1W0EP0	15	73	17
69103 G000003	SBS	1971	16.1	2114	361	241	AT55PL29SW7BL5EP4	20	52	20

ANNEX 2: NATURAL REGENERATION DATA FROM 96 MPB-STUDY PROJECT GN-PSPs

Note: Class_0 is all stems 0.3 m-1.29 m tall; Class_1 is all stems > 1.3 m tall and DBH < 2.0 cm. Meas_no is the measurement number at the 2012/2013 assessment.

SAMP_ID	*Meas_no*	*Species*	*Regeneration Density (stems/ha)*		
			Class_0	*Class_1*	*Total*
25021 G000004	3	BL	200	200	400
34001 G000006	3	FD	433	100	533
34001 G000006	3	PY	33	0	33
35001 G000001	1	FD	520	0	520
35001 G000001	1	PY	560	0	560
47007 G000001	3	FD	333	500	833
47009 G000002	2	AT	400	0	400
47013 G000003	1	AT	2333	133	2467
47013 G000003	1	SX	133	0	133
47013 G000004	1	AC	300	0	300
47013 G000004	1	AT	2250	1050	3300
47013 G000004	1	SX	50	0	50
47017 G000007	2	EP	67	0	67
47017 G000007	2	FD	0	67	67
47026 G000003	4	FD	2000	800	2800
47026 G000007	4	FD	1000	500	1500
47026 G000007	4	PL	0	0	0
47026 G000007	4	SX	1000	200	1200
47026 G000007	4	W	0	100	100
47026 G000008	4	FD	0	42	42
47026 G000008	4	SX	0	42	42
47029 G000001	5	FD	571	143	714
47029 G000001	5	PL	1571	286	1857
47029 G000002	5	AT	500	0	500
47029 G000002	5	FD	200	800	1000
47029 G000002	5	PL	2300	100	2400
47030 G000001	4	AT	400	0	400
47030 G000001	4	FD	50	50	100
47030 G000001	4	PL	2350	250	2600
47030 G000002	5	PL	400	200	600
47030 G000007	5	FD	143	0	143
47030 G000007	5	PL	429	143	571
47030 G000008	4	FD	67	0	67
47030 G000008	4	PL	3333	67	3400

SAMP_ID	*Meas_no*	*Species*	*Regeneration Density (stems/ha)*		
			Class_0	*Class_1*	*Total*
47057 G000002	2	AT	300	0	300
47057 G000003	2	FD	50	250	300
47059 G000001	2	FD	400	600	1000
47059 G000002	2	AT	571	0	571
47059 G000002	2	FD	0	143	143
48011 G000001	1	SX	25	25	50
48011 G000002	1	PL	0	50	50
48012 G000002	2	FD	286	857	1143
48013 G000003	1	PL	2400	1000	3400
48013 G000004	1	BL	10	0	10
48013 G000004	1	PL	410	10	420
48013 G000004	1	S	140	40	180
48013 G000005	1	PL	286	714	1000
48013 G000005	1	S	143	0	143
48013 G000006	1	BL	3840	40	3880
48013 G000006	1	SX	160	0	160
48014 G000002	1	PL	5000	2000	7000
48014 G000002	1	S	0	500	500
48014 G000004	1	S	25	0	25
48014 G000005	1	SX	0	25	25
48014 G000006	1	SX	800	200	1000
48018 G000001	1	PL	400	1200	1600
48018 G000001	1	S	200	0	200
48058 G000001	2	FD	2200	2000	4200
48058 G000001	2	PL	1000	0	1000
48058 G000001	2	SB	400	200	600
48059 G000005	2	FD	4857	5286	10143
48060 G000005	1	FD	4500	3000	7500
55015 G000001	1	BL	5000	2000	7000
55015 G000001	1	PL	0	500	500
56019 G000002	1	BL	8286	571	8857
56019 G000002	1	CW	1143	857	2000
56019 G000003	2	BL	40	0	40
56019 G000003	2	FD	0	40	40
56019 G000003	2	S	80	80	160
56019 G000004	1	BL	3067	267	3333
56019 G000004	1	SW	200	0	200
56023 G000003	2	EP	0	500	500
56023 G000003	2	FD	0	1000	1000
56023 G000003	2	SW	35000	18000	53000
56023 G000005	2	FD	0	333	333

SAMP_ID	Meas_no	Species	Regeneration Density (stems/ha)		
			Class_0	Class_1	Total
56023 G000005	2	S	333	1333	1667
56023 G000007	1	FD	667	667	1333
56023 G000007	1	PL	0	333	333
56023 G000007	1	SW	333	1000	1333
56049 G000054	1	BL	16000	0	16000
56049 G000054	1	CW	7000	1500	8500
56052 G000001	2	AT	1100	50	1150
56052 G000001	2	PL	250	50	300
56052 G000002	1	PL	0	1000	1000
56052 G000002	1	SX	1000	333	1333
56053 G000100	3	FD	700	0	700
56053 G000100	3	S	100	100	200
56054 G000006	2	AT	200	200	400
56055 G000005	2	AT	0	100	100
56055 G000005	2	SX	750	150	900
56055 G000006	1	AT	333	1000	1333
56055 G000006	1	PL	0	667	667
56055 G000006	1	SX	1000	1000	2000
56055AG000008	1	BL	714	0	714
56055AG000008	1	SX	143	0	143
56057 G000002	1	BL	40	0	40
56057 G000002	1	CW	760	200	960
56057 G000002	1	HW	40	0	40
56066 G000002	1	BL	200	0	200
56066 G000002	1	CW	0	400	400
56067 G000002	1	BL	5000	333	5333
56069 G000001	1	FD	1200	200	1400
56069 G000001	1	SW	2800	1000	3800
56069 G000002	2	FD	50	50	100
57016 G000002	2	AT	0	100	100
57016 G000002	2	BL	0	50	50
57016 G000002	2	FD	100	200	300
57016 G000002	2	SX	0	200	200
57017 G000008	2	AT	1667	667	2333
57017 G000009	2	AT	1450	1550	3000
57017 G000009	2	PL	0	0	0
57017 G000009	2	SW	250	300	550
57017 G000010	2	AT	7400	2867	10267
57017 G000010	2	PL	67	0	67
57017 G000010	2	SX	67	0	67
57018 G000004	2	B	67	33	100

SAMP_ID	Meas_no	Species	Regeneration Density (stems/ha)		
			Class_0	Class_1	Total
57018 G000004	2	CW	100	0	100
57018 G000004	2	FD	100	67	167
57018 G000004	2	S	33	33	67
57018 G000006	2	B	1714	714	2429
57018 G000006	2	SX	429	143	571
60082 G000025	1	BL	6500	500	7000
60132 G000038	2	AC	0	0	0
60132 G000038	2	AT	150	0	150
60132 G000038	2	BL	50	0	50
60132 G000038	2	PL	75	0	75
60132 G000038	2	SX	88	0	88
60136 G000003	4	BL	1900	200	2100
60136 G000003	4	SX	100	0	100
60136 G000004	4	BL	800	600	1400
60136 G000004	4	SW	200	400	600
60136 G000062	1	BL	3500	300	3800
60136 G000062	1	SW	200	0	200
60136 G000063	1	BL	900	100	1000
60136 G000063	1	SW	25	0	25
60136 G000064	1	BL	1367	33	1400
60137 G000029	2	BL	975	0	975
60137 G000029	2	SW	25	0	25
60148 G000023	1	BL	8200	800	9000
60148 G000023	1	SW	200	0	200
60150 G000004	4	BL	6200	600	6800
60150 G000004	4	SW	200	0	200
60150 G000007	4	BL	1800	600	2400
60150 G000009	4	BL	1000	1200	2200
67008 G000043	2	BL	2467	33	2500
67023 G000051	1	BL	0	67	67
67023 G000051	1	PL	133	1267	1400
67024 G000127	1	BL	1200	1100	2300
67024 G000128	1	BL	5600	600	6200
67024 G000128	1	SW	400	0	400
69018 G000001	3	BL	1700	0	1700
69018 G000010	3	BL	600	150	750
69018 G000010	3	SW	400	50	450
69018 G000011	3	BL	967	133	1100
69018 G000011	3	SW	233	67	300
69018 G000013	3	BL	667	333	1000
69018 G000017	1	BL	1760	280	2040

SAMP_ID	Meas_no	Species	Regeneration Density (stems/ha)		
			Class_0	Class_1	Total
69018 G000017	1	PL	200	40	240
69018 G000017	1	SX	80	0	80
69018 G000018	1	BL	18000	1000	19000
69019 G000002	3	BL	1100	0	1100
69019 G000002	3	PL	0	0	0
69019 G000002	3	SW	900	0	900
69019 G000009	1	BL	160	0	160
69019 G000009	1	PL	40	0	40
69019 G000009	1	SX	920	40	960
69022 G000007	4	BL	600	0	600
69022 G000007	4	SX	800	0	800
69022 G000015	1	BL	175	25	200
69022 G000016	1	BL	6200	400	6600
69022 G000016	1	PL	600	600	1200
69022 G000018	1	BL	2000	100	2100
69022 G000018	1	PL	400	0	400
69022 G000018	1	SW	500	100	600
69049 G000002	1	BL	533	67	600
69049 G000002	1	EP	67	67	133
69049 G000002	1	PL	3133	0	3133
69049 G000002	1	SB	1200	133	1333
69049 G000002	1	SW	1200	67	1267
69062 G000001	4	BL	440	40	480
69062 G000001	4	SW	80	80	160
69062 G000002	4	BL	1400	633	2033
69062 G000002	4	SW	133	133	267
69062 G000005	4	BL	4000	0	4000
69062 G000005	4	SW	400	0	400
69099 G000006	1	BL	29000	2500	31500
69103 G000003	4	BL	728	556	1284
69103 G000003	4	SX	0	12	12

ANNEX 3: PRELIMINARY PROCEDURES FOR MEASURING WEATHER CHECKS AND SPIRAL GRAIN

The following procedures were suggested by Bob Macdonald several years ago.

Weather Checks procedure:

A weather check is defined as a radial split in the bole of the tree that is at least 2 cm deep.

Check depth will be measured by the use of a stainless steel putty knife that is 0.5mm thick and 4 cm wide. The checks will be coded based on depth and frequency. Use a metal scale ruler for check depths greater than 9 cm.

Step 1

If applicable, measure and record the DBH, net factors, call grades of the tree, before stripping the bark.

Step 2

In order to measure the checks remove the bark from the tree in the area between 1.0 metre and 1.3 metres (DBH) above high side ground. All measurements of checks must be done in this 30 cm area around the stem. A draw knife has been found to work the best at bark stripping and a hatchet may be required for furrowed areas. If the cruiser determines that a given tree is unsafe to strip the bark with a draw knife they may drop the tree and put comments in the notes as to why the tree was dropped (EG tree 2 dropped as it is close to toppling)

Step 3

In the bark stripped area, conduct a cursory inspection of the checks with depths greater than 2 cm and orientate the quadrants to maximise the number of check free quadrants. Mark the quadrants on the tree with a felt marker. Use a diameter tape to determine quadrant boundaries by dividing the diameter by 4. Quadrant 1 will be the one facing plot centre; the remaining quadrants are numbered to the right of quadrant 1 as you are facing the tree.

Step 4
Measure the depths of the deepest check in each quadrant to the nearest centimetre for all checks with depths greater than 2 cm

Step 5
Record the depth in centimetres of the deepest check in each quadrant.

Spiral Grain Procedure:

The deflection of spiral grain is measured anywhere along the 30 cm area from 1.0 to 1.3 metres as per the diagram below. Measure the displacement of the grain to the nearest centimetre along a 30 cm transect and record in the spiral grain column on the attached tally card. Spiral grain deflection of 9 cm or more will be recorded as 9 cm.