Executive Summary

Regeneration and Stand Structure following Mountain Pine Beetle infestation in the sub-boreal spruce zone.

Project Y061148

Project Purpose and Management Implications:

Due to the overwhelming magnitude of the Mountain Pine Beetle (MPB) epidemic, management emphasis has shifted from efforts to control the epidemic to efforts to mitigate its impact on communities and the environment. The Allowable Annual Cut has been increased in most management units which may lead to a fall-down in timber supply in the medium to long term. It is likely that significant areas of infested forest will never be salvaged due to the large area that is impacted. Forest managers must now make decisions about which stands should be salvaged, which should be left to regenerate naturally, and which stands may require rehabilitation.

The mountain pine beetle outbreak is leaving residual stand structures consisting of scattered or clumped surviving lodgepole pine trees, interior spruce and subalpine fir of different sizes and ages, and patches of assorted hardwood species. As many of the heavily hit stands (especially the remote ones) will never be salvaged, the future dynamics of these stands and their ability to contribute to the timber supply is largely unknown. There is little or no data on how these complex, unmanaged stands will regenerate. Where forest managers do harvest stands following MPB, they are frequently leaving behind significant amounts of in-stand structure, in order to mitigate the possible environmental impacts of salvage operations, and to mimic the stand structures that would follow a natural disturbance. The regeneration in these complex managed stands is not well understood.

Managers need a variety of modelling tools to assist with these decisions, to predict the long-term consequences of the beetle infestation, and to explore possible management responses to it. These modelling efforts face two barriers: 1) incomplete data on regeneration and stand structure following Mountain Pine Beetle, and 2) models are not available for these ecosystems to predict growth and yield in complex stands. Existing forest growth models (e.g. TASS/TIPSY) were developed for contemporary forest management, largely even-aged stands with little or no in-stand structure. They were not designed to deal with the complex stands that will regenerate after Mountain Pine Beetle. In contrast, SORTIE is specifically designed to simulate the development of irregular multi-species stands (Coates et al. 2003)

This project will prepare a comprehensive data set that describes stand structures and regeneration found following pine beetle attack, across diverse site types, from one to ten years following attack, and across several biogeoclimatic subzones in the north-central Interior.

The data from this project will have immediate application through the analysis and description of relationships between ecosystems, stand structure, and regeneration. The data will also have long-term benefits because it will allow researchers to improve models of regeneration, growth and yield, and timber supply. Those models are widely applied in forest management, so the impact of improved data is widespread. The data will be collected so that it can specifically be used in models that are currently being applied in the study area. Models used for Sustainable

Forest Management Plans in the Lakes and Morice IFPA area can be updated with the data that is collected, with a focus on successional pathways and growth and yield. Further development of SORTIE-ND will be enabled through the use of this dataset to refine tree recruitment models.

The project will show forest managers which stands will have the highest success of regenerating naturally. Based on anecdotal information, some ecosystems may regenerate very quickly and fully following MPB, while others will not. If these differences are significant, then allowing certain stands to regenerate naturally will have significantly larger timber supply impacts than other stands. Knowing which stands have the best chance of successful regeneration will allow forest managers to prioritise stands for harvest in a way that will reduce the size of the anticipated fall-down to the AAC. Even a small reduction in the long-term fall-down will have large benefits by reducing the impact on communities, reducing the social costs of transition, and ensuring that long-term revenues from the forest remain stable.

Project start date: May 1, 2005

Length of Project: May 1, 2005 to March 31, 2007

Former Project numbers of funding sources: none applicable

Methodology Overview:

A. Project Objectives:

1. Quantify tree seedling recruitment across the full range of stand types affected by MPB. Two critical factors affecting recruitment success will be assessed: abundance of parent trees and seedbed substrate favourability.
2. Develop, test and parameterize non-spatial recruitment models for MPB damaged forests that can be incorporated into stand and landscape dynamics models.
3. Determine the relative importance of long-distance versus local dispersal.

B. Sampling methods:

A sample site is comprised of two components: a “seed source” stand (a non-pine leading stand type) and an adjacent pine-leading stand. Sample sites are selected using the following criteria:

- Presence of a seed source stand composed primarily of mature non-pine species.
- A large adjacent pine leading stand attacked by MPB
- No recent disturbance that would affect natural regeneration or seed tree abundance

Sampling a site involves assessing the species composition and basal area of the seed source stand and more detailed assessments of site conditions, natural regeneration, and stand structure in the pine leading stand.

Seed Source Sampling: Three variable radius prism plots are established in the seed source stand in order to characterise the species composition and abundance (basal area) of potential parent trees (seed source).

Pine Stand Sampling: A transect is established through the adjacent pine type perpendicular to the boundary between the two types. Plots are located at variable distances along the transect. Each plot in the pine type consists of a nested set of fixed and variable radius plots established to measure all trees from seedlings to mature trees. The plot centre is GPS'd. Seedlings that have established post-MPB attack (natural regeneration) are identified by species and tallied in a 3.99m radius plot. Substrate distribution is recorded within this plot and the substrate each germinant is located upon is recorded. The 3.99m plot is also used to tally advanced regeneration (established pre-MPB attack) by species in the following classes: 0 to 10 cm tall, 10cm to 30cm, 30cm to 1.3m tall, and 1.3m tall to 7.5cm DBH. Acceptability of advanced regeneration is tallied based upon the condition of the tree and the expected capacity of each tree to respond to release post-MPB. A variable radius prism plot is used to record overstory trees (>7.5cm DBH) by species, diameter and condition (live/dead). Co-dominant and dominant parent trees of species that are a minor component of the stand are recorded within a larger search radius around the plot centre (from 15m to 50m radius depending upon parent abundance).

We also record forest cover polygon information from the pine leading stand and adjacent polygons to provide a measure of parent abundance that can be used for parameterization of a long distance dispersal term. Other information collected includes biogeoclimatic ecosystem site classification and an estimate of age since MPB attack based upon an assessment of the condition of the overstory.

C. Data analysis:

We will attempt to parameterize recruitment models for all major tree species in these forests: lodgepole pine (*Pinus contorta* var. *latifolia* Dougl. ex Loud.), interior spruce [*Picea glauca* (Moench) Voss x *P. engelmannii* Parry ex Engelm.], subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.), Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco), paper birch (*Betula papyrifera* Marsh.), trembling aspen (*Populus tremuloides* Michx.) and black cottonwood (*Populus balsamifera* ssp. *trichocarpa* Torr. & Gray).

We will use maximum likelihood procedures and simulated annealing (a global optimization algorithm) to determine the most likely parameters (i.e. the parameters that maximize the log-likelihood), given our observed data set (Goffe et al. 1994). We will use Akaike Information Criterion (AIC) (Burnham and Anderson 2002) to select the model(s) that are best supported by the data.

Project Scope and Regional Applicability:

Because the data will cover the sub-boreal spruce (SBS), sub-boreal pine - spruce (SBPS) zones and Engelmann spruce - subalpine fir (ESSF), the project will be applicable to the most heavily impacted areas of the province that are affected by Mountain Pine Beetle. The management units that would benefit from the study (Morice TSA, Lakes TSA, Bulkley TSA, Prince George TSA, Mackenzie TSA, Quesnel TSA) make up almost 20 million m3 of AAC per year.

Interim Conclusions and Information:

A. Project Progress:

Sampling for this project will span two field seasons. We are collaborating with other FSP funded research groups collecting data in beetle damaged stands. Our responsibility was the design of the natural regeneration sampling. A group lead by Phil Burton, CFS, Prince George co-ordinated advance regeneration sampling. Debbie Cichowski, BV Research Centre, Smithers, added natural regeneration sampling to her sampling design of re-measured plots. In total the three research groups established 337 natural regeneration plots across a wide gradient of site types (Table 1) between Houston to Prince George centred along Highway 16, and in stands with varying lengths of times since MPB attack (Table 2).

Sample sites were selected to maximize variability in local and long-distance parent tree abundance and to maximize seedbed substrate variability. Distribution of sample sites was not equally distributed across sites or age since MPB attack due to differences in abundance and accessibility of these stands.

Additional plots will be established in the second field season. The majority of these plots will be established in older beetle attacked stands to improve sample sizes where regeneration is occurring. We found limited natural regeneration in younger attacked stands. To focus on the factors affecting regeneration we need to sample in areas more likely to have regeneration – older attacked stands. We will also expand our sampling to the ESSF and SBPS zones in the second year of the project.

Biogeoclimatic subzone and variant	Sites Series							
	01	**02**	**03**	**04**	**05**	**06**	**07**	**09**
SBSdk	7	0	30	0	39	3	0	0
SBSdw3	16	0	35	20	59	2	2	1
SBSmc2	68	11	0	n/a	6	1	0	0
SBSmc3	10	0	0	21	0	0	0	0

Table 1. Number of plots established within each site series in the SBS.

Years since MPB attack	Number of Plots
0	10
1	44
2	76
3	68
4	39
5	8
6	35
7	29
9	18

Table 2. Summary of plots by year since MPB attack.

B. Preliminary Information:

The initial results from the first field season show that natural regeneration established post-MPB attack is limited throughout the sampling area. We found little regeneration of any species in younger (1-4 yrs) attacked stands. Natural regeneration abundance began to increase in stands that had been attacked at least four years previously. The intent of the first year of sampling was to evenly sample the full gradient of stand ages since MPB-attack. Older stands are not as prevalent and access is limited. As a result, the number of plots with established natural regeneration is limited after one year of sampling. We can, however, draw some preliminary conclusions.

Regeneration and time since MPB attack:
Successful establishment of lodgepole pine, interior spruce, and subalpine fir regeneration begins approximately four years post-MPB attack (Fig. 1). This may be related to the length of time required for the MPB attacked pine to lose needles and fine branches and for light levels to begin increasing under MPB attacked stands. Germination, survival and growth of seedlings should improve as light levels increase. No trembling aspen regeneration was found in the 337 plots established.

Proximity and abundance of seed trees:
We were surprised at how common non-pine seed trees were in pine-leading stand types. Our original idea was to get a gradient of non-pine parent abundance by moving away from a major non-pine seed source into a pine leading stand type. Non-pine parent trees were always around providing a seed source. Our preliminary graphical analysis shows that natural regeneration occurs regardless of distance from a large seed source (Fig. 2), although very high densities of subalpine fir regeneration appear to only occur close to a major seed source. Our planned statistical analysis will be able to do a better job of parsing out the influence of parent tree proximity and abundance on natural regeneration success.

Site type and seedbed substrate:
In general, regeneration appears to be most successful on substrates that provide seedlings with access to consistent moisture levels and that were not heavily shaded by herbs and shrubs. Very poor regeneration occurred on the rich, moist site series that were dominated by well developed vegetation layers shading regeneration sites. On the mesic sites, regeneration tended to be found on sites with a less vigourous moss layers. Regeneration success was best on the following sites: SBSdk 03 (subxeric, poor), SBSdk 05 (submesic to mesic, poor), SBSmc2 02 (xeric to subxeric, poor), SBSmc2 01 (submesic to mesic, poor to rich), SBSdw3 05 (submesic to subhygric, poor), and SBSdw3 04 (submesic, poor to rich).

The two most common seedbed types were moss (canopy moss) and conifer litter (Fig. 3). Of these two, conifer litter appeared to be a more favourable substrate than canopy moss (Fig. 3). Where conifer litter is present moss growth is less vigourous than the surrounding unaffected canopy moss.

C. Extension:

The success of natural regeneration after beetle attack is a topic of considerable interest to the forestry community. We have taken every opportunity to explain this project and our preliminary findings. Our extension activities are ongoing. Major extension events in the first year of the project were:

i. Two meetings with professors and students at UBC including collaboration on regeneration issues with Prognosis modeling group.
ii. Talk by Coates at the Northern Silviculture Committee 2006 Winter Workshop titled "Silvicultural Approaches to Managing MPB Damaged Stands: Regeneration and Mid-term Timber Supply", January 2006, Prince George.
iii. Meetings with government and forest company staff in Skeena Stikine, Nadina and Vanderhoof Forest Districts (November-January).
iv. Talk by Coates to Northern Interior Forest Region Management Team meeting, October 2005, Prince George.

Concluding statement

This is a difficult project. Whenever you get a large numbers of zero data points in a dataset it makes statistical analysis problematic. This has certainly been the case with our preliminary analysis. We hope to improve this situation with focused sampling in the second year. That said, we have learned a lot about regeneration dynamics after mountain pine beetle attack. It is clear that little regeneration occurs in the first few years across all sites types. Regeneration appears to be very poor on the richer sites at all ages since beetle attack because existing herb and shrub layers are responding rapidly to improved growing conditions and shading out regeneration sites. On mesic and drier site types regeneration begins to develop 4-5 years after beetle attack. We hope to further refine our understanding of the dynamics that are controlling regeneration success on these site types in the second year.

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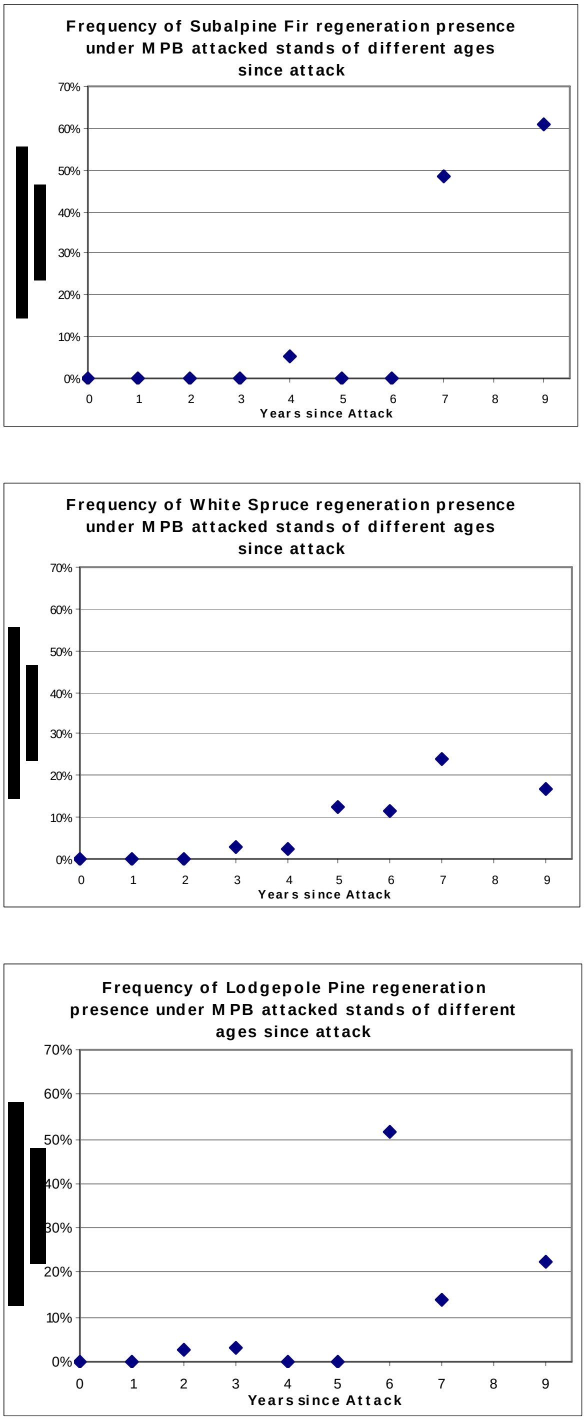

Figure 1. Frequency of subalpine fir, white spruce, and lodgepole pine regeneration shown as the percentage of plots in which established regeneration was tallied for each age class of MPB-attacked stands**.**

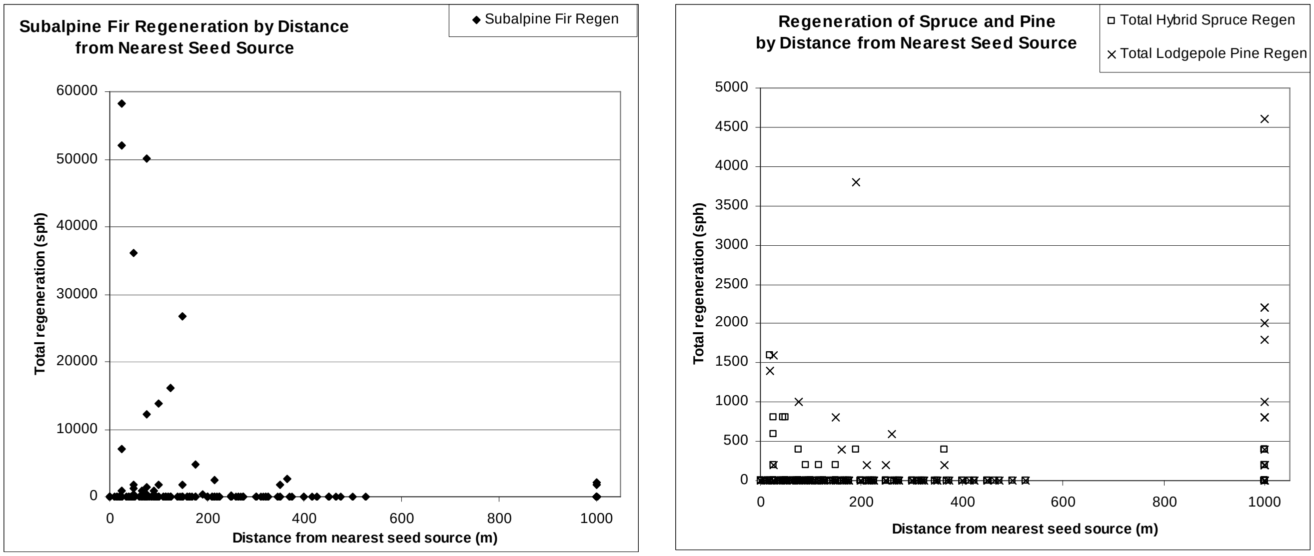

Figure 2. Effect of distance from large seed source on abundance of subalpine fir, hybrid spruce, and lodgepole pine natural regeneration.

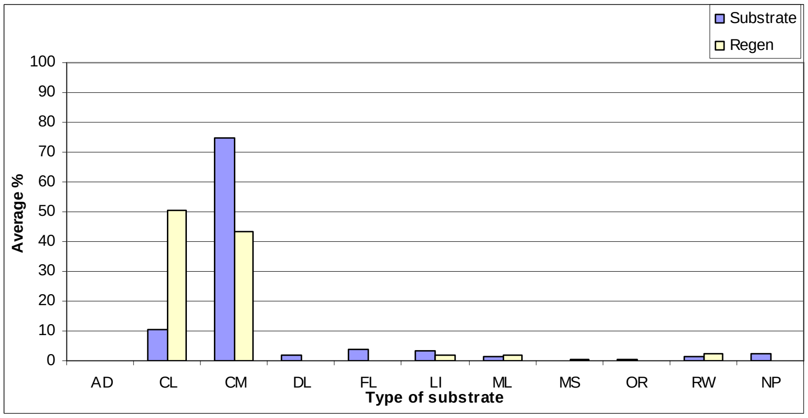

Figure 3. Percent distribution of substrate and regeneration across all plots.