Executive Summary

FIA-FSP Project number: M07-5044
Project title: Stand dynamics following mountain pine beetle outbreaks in central British Columbia: a synthesis for decision-support

Project Purpose and Management Implications:

As a natural agent of disturbance, mountain pine beetle outbreaks play an important functional role in directing ecological processes and maintaining biological diversity of forest ecosystems. However, having infested 9.2 million hectares of lodgepole pine forests to date (BC Ministry of Forests and Range 2007), the current beetle outbreak is unprecedented in scale. Mortality is severe in about 25 percent of the infested forests. As lodgepole pine comprises about one quarter of the provincial timber supply, socioeconomic impacts of this outbreak are enormous. A variety of silvicultural tools and management strategies can be used to reduce the effects of timber losses, the most important tool being salvage logging. In the short-term, adjusting harvest scheduling to remove standing beetle-killed trees can compensate some of the timber losses. However, due to numerous market, operational, legal, and ecological constraints the proportion of the beetle-killed forests that can be salvage-logged is limited.

As the outbreak continues, and especially after its eventual collapse, forest managers will need to develop strategies to manage the large areas left unsalvaged. For this they will need to quantify the basic stand dynamics processes associated with mountain pine beetle outbreaks, such as host mortality, post-outbreak stand growth, recruitment rates and species composition following mountain pine beetle (MPB) outbreaks. Currently, this information is scant and our ability to estimate the long-term impacts of beetle outbreaks on BC forests is, therefore, limited.

Throughout much of British Columbia, lodgepole pine occurs as a seral species forming even-aged stands initiated by stand-replacing fires. Although such dynamics are considered typical for the species, uneven-aged lodgepole pine stands that have historically been maintained by frequent low-intensity surface fires are frequent in central BC. Forest landscapes of central BC are dominated by lodgepole pine and can generally be described as a mosaic of even-aged and uneven-aged stands (Agee 1993). However, the disturbance ecology of these forests is changing. The frequency of fires has decreased over the last century mostly due to effective fire suppression programs. When fire is infrequent, outbreaks of mountain pine beetle are likely to have a greater impact on forest structure, composition and dynamics. However, we know surprisingly little about the changes in forest characteristics following beetle outbreaks. Roe and Amman (1970) studied the dynamics of lodgepole pine stands in areas of western USA infested by mountain pine beetle and, more recently, Hawkes et al. (2004) studied stand composition following the 1980s outbreak in central BC.

MPB outbreaks have long occurred British Columbia (Alfaro et al. 2004, Alfaro and Campbell 2006). Massive mortality caused by beetle outbreaks releases resources that are potentially available to outbreak survivors (either lodgepole pine or other species that occur on the site), and to recruitment individuals that subsequently become established (Heath and Alfaro 1990). Therefore, in addition to mortality, outbreaks also affect tree growth rates and establishment patterns, which in turn, alter stand productivity, structure, and composition. Conceptual models

of succession in pine ecosystems suggest that beetle outbreaks may, in the absence of fire, accelerate the successional process in favour of non-susceptible trees (Veblen et al. 1991). We suspect that this proposition is correct for even-aged lodgepole pine stands, but will be less appropriate in uneven-aged stands. We propose that in at least some uneven-aged stands the response to canopy mortality may be increased growth of surviving, small lodgepole pine, in a self-perpetuating lodgepole pine climax.

Fundamental to achieving the goal of sustainable forest management in areas infested by mountain pine beetle are reliable decision support tools (e.g., stand dynamics models) that incorporate the impacts of beetle outbreaks into forecasts of future stand conditions and projections of future timber supplies. However, we still lack information necessary to reliably implement these tools in some forests, particularly uneven-aged lodgepole pine forests. This project aims a filling these information gaps and addresses the following questions:

1. What is the composition of residual forests left after beetle epidemics?
2. What is the future composition and growth of the residual forests?
3. How future management interventions may alter future path of affected stands, thereby leading to long-term future compensation for beetle-related losses.

Project Information:
Start date – April 2006
Length of Project – 2 years (April 2006 – March 2008)

Methodology Overview
Overstory Stand Structure: We will intensively sample 3 even-aged and 3 uneven-aged stands to reconstruct the dynamics of these stands. Data from this work will indicate how stands progressed towards their present day composition and structures. As much as possible we will use the same stands sampled by Hawkes et al. (2004) and Alfaro et al. (2004).

Within each stand we will establish four 5.45 radius circular plots (0.01 ha), located every 50 meters, in a diamond or linear pattern depending on the stand boundaries. To avoid stand edge effects, all plots will be located at least 50 m from the stand borders. A variety of stand mensuration data will be collected, including: height, diameter-at-breast height (DBH), beetle status (healthy, green attack, red, or grey), crown class, wildlife tree condition and other pathological indicators.

Regeneration and recruitmen: One regeneration recruitment subplot will be established in each of the four plots per stand (i.e., 4 regeneration plots per stand). If there are a large number of saplings and seedlings the regeneration plot will consist of a 3.99 radius plot (0.005ha) centered in each overstory plot, otherwise the plot radius will remain the same (5.64m). We will record the species, height and density. A sub-sample of the regeneration tree species will be aged to establish recruitment episodes.

Stand Reconstruction: We will collect increment cores for dendroecological analysis. The purpose of this collection is to establish the MPB disturbance and stand development history of the stands sampled for temporal reconstruction. Cores from at least 5 sample trees in each 5cm diameter class, from lodgepole pine and other species on the site will be collected to establish

similar age cohorts. Cores and or basal discs will be collected from dead trees and down coarse woody debris, to establish possible waves of mortality due to past outbreaks or fire occurrences.

Tree-ring chronologies developed by Alfaro et al. (2004) and Campbell and Alfaro (2006) will be used to cross-date new tree ring data collected in this project. This will ensure accurate estimates of recruitment and tree death dates, information that will be used to describe temporal patterns in recruitment and mortality (e.g., frequency distributions) for all species.

Data analyses: We will use simple descriptive statistics and graphic analyses to describe stand development, overstory and understory, over time. Non-parametric tests (*Chi* square tests, Kruskall Wallis ANOVA) will be used to test for differences in current stand composition and age distribution between even and uneven-aged stands.

*Modelling future stand composition***:** In collaboration with the B.C. Ministry of Forests, we will incorporate these data into model simulations of stand dynamics following beetle outbreaks in central British Columbia. The Tree and Stand Simulator (TASS) will be used for even-aged stands and for uneven-aged stands we will use Prognosis^{BC}. The horizon for the projection of growth and yield will be 120 years, which is the average age of an "old" lodgepole pine stand in the area.

The purpose of modeling is to develop a series of case studies using different beetle risk scenarios. Scenarios will consist of simulating outbreaks of different frequency, intensity and duration. Frequency of outbreak will vary from none to 4 outbreaks per century. Varying the number of trees killed by diameter class will represent MPB attack intensity. Duration of outbreaks will be based on stand reconstruction data. Data collected from previous studies and from the stand reconstruction studies will be used as inputs for the simulations. Output will be presented as a series of decision-aid tables (similar to TIPSY) that will indicate future yield and stand composition under the various scenarios.

Contact Information:

Proponent Name: Dr. René Alfaro, Senior Research Scientist
Proponent Organization: Pacific Forestry Centre, Canadian Forest Service
Mailing address: 506 Burnside Rd. West
E-mail address: ralfaro@nrcan.gc.ca
Telephone number: 250-363-0660
Fax number: 250-363-0775

Project Scope and Regional Applicability

This project unravels stand dynamics in a set of stands that are representative of large portions of the interior lodgepole pine ecosystems of BC (IDFdk BEC subzone). Therefore, the information provided will be of high interest to forest managers concerned with post beetle management. Results of this work will provide foresters and managers an idea of what types of forest structure will be left in unsalvaged stands, including their stand structure, tree species recruitment rates and frequency of mountain pine beetle disturbance.

Interim Findings

Stand dendrochronological and mensuration data from three even-aged sampled stands in the Logan Lake area in the southern interior of BC provided a current snapshot of stand structure in

the IDFdk subzone undergoing a MPB outbreak. The following are some of the characteristics of these stands:

- In the IDFdk1 subzone of the southern interior region there are extensive tracts of lodgepole pine leading stands with some Douglas-fir veterans interspersed in the stands and along their edges.
- The lodgepole pine overstory had the highest stand density in the 5.1-10 and 10.1-15cm DBH classes.
- In all stands, MPB attack and subsequent mortality started in the 5.1-10cm DBH class, with pine in the >15.1cm DBH class almost entirely attacked and killed by MPB.
- In all stands, even with MPB mortality, stocking exceeded the minimum stocking standards (500 sph of which 400 sph must be primary species) for the IDF (BC Ministry of Forests and Range 2000)
- All three stands had both green attack trees (attack in year of survey) and red attack trees (attack in previous 5 years). The southernmost stand, Stand 3, had grey attack (attack >5 years ago) suggesting that this stand had undergone the longest MPB outbreak.
- Stand density by DBH and height, and tree age showed a number of understory lodgepole pine cohorts existed that did not reflect the expected "classic" even-aged stand structure, suggesting that the IDFdk1 subzone is better characterized as being "quasi" even-aged, at least in the area that stands were sampled. The presence of fire scars on overstory lodgepole pine in the sampled stands suggest that they have experienced some low to moderate severity fires, in addition to the stand replacement and high severity fires that were responsible for stand initiation.
- Sapling and seedling density was found to be below the Ministry of Forests stocking standards for the Kamloops Timber Supply Area, especially in Stand 3, where they were almost non-existent.
- Lodgepole pine saplings took, on average, 15 years to reach DBH, while Douglas-fir took, on average, 50 years. The relatively long period of time that was needed to reach DBH was due mainly to the high amount of crown closure.
- The low stocking of lodgepole pine saplings and their average mortality (36%) suggest that natural regeneration will not be sufficient to restock unsalvaged stands, with the degree of overstory mortality by MPB.
- Coarse woody debris in all decay classes ranged from 18 to 55 m^3/ha, indicating a high degree of variation among the stands sampled.

A preliminary conceptual model of stand dynamics in these"quasi" even-aged lodgepole pine stands was developed and indicated that there was a cyclic nature to the stand disturbances in the southern interior. Based on our analysis and stand reconstructions, stands historically established through an age-independent disturbance, such as a high severity crown fire, and from this type and intensity of disturbance created seral even-aged lodgepole forests. The occurrence of age and diameter-dependent disturbances, such as MPB outbreaks, resulted in significant levels of lodgepole pine tree mortality; the creation of additional (to what was already present from the previous fire killed trees that had fallen over) CWD volumes, crown openings, and eventually growth release of the residual stand. Understory tree regeneration after initial stand establishment

created stand structures consisting of two cohorts. The understory tree cohort was found to have 36% mortality, likely due to increases in crown closure since stand initiation, inter-tree competition and continuous grass cover. If succession was to progress to an old stand, one would expect at some point in time, a crown or surface fire, that would either replace the existing stand or thin it. In the absence of fire, that disturbance cycle is truncated, so that the stand is then only disturbed by other disturbances like MPB and wind.

In these "quasi" even-aged lodgepole pine stands, the dendrochronological and stand mensuration data indicated that stand replacement disturbances like fire play a key role in the ecological processes of lodgepole pine stands. Stand replacement fires initiate even-aged lodgepole pine stands, while multiple MPB disturbances and surface fires shape forest successional pathways and stand structure and dynamics. Clearly, in the absence of a fire disturbance (through fire suppression), mountain pine beetle has played a more frequent and important role in directing stand dynamics and structure in the southern interior of BC.

References Cited

Agee, J.K. 1993. Fire ecology of the Pacific Northwest Forests. Island Press, Washington DC. 493pp

Alfaro, R.I., R. Campbell, P. Vera, B. Hawkes and T. Shore. 2004. Dendroecological reconstruction of mountain pine beetle outbreaks in the Chilcotin Plateau of British Columbia. Pages 245-256, in T.L. Shore, J.E. Brooks and J.E. Stone (Eds.) Mountain Pine Beetle Symposium: Challenges and solutions. Natural Resources Canada, Canadian Forest Service, Pac. For. Centre, Victoria, BC, Canada. Inf. Rep. BC-X-399. 287 pp.

British Columbia Ministry of Forests and Range. 2007. 9.2 million hectares affected by mountain pine beetle. Press Release: February 19, 2007, Victoria, British Columbia, Canada. http://www2.news.gov.bc.ca/news_releases_2005-2009/2007FOR0011-000152.htm

British Columbia Ministry of Forests and Range. 2000. Establishment to free growing guidebook Kamloops Forest Region, Revised edition 2.2. BC Ministry of Forests, Victoria BC.

Campbell, E. and R. Alfaro, 2006. Historical frequency, intensity and extent and of mountain pine beetle outbreaks in landscapes of British Columbia and Alberta. Canadian Forest Service. MPBI Project Report #2.05

Hawkes, B., S.W. Taylor, C. Stockdale, T.L. Shore, R.I. Alfaro, R. Campbell and P. Vera. 2004. Impact of the mountain pine beetle on stand dynamics in British Columbia. Pages 177-199, in T.L. Shore, J.E. Brooks and J.E. Stone (Eds.) Mountain Pine Beetle Symposium: Challenges and solutions. Natural Resources Canada, Canadian Forest Service, Pac. For. Centre, Victoria, BC, Canada. Inf. Rep. BC-X-399. 287 pp.

Heath, R. and R. Alfaro. 1990. Growth response in a Douglas-fir/lodgepole pine stand following thinning of lodgepole by the mountain pine beetle: a case study. J. Entomol. Soc. BC. 87:16-21.

Roe, A.L. and G.D. Amman. 1970. The mountain pine beetle in lodgepole pine forests. USDA For. Serv., Intermountain Res. Stn. Ogden, UT. Res. Pap. INT-71.

Veblen, T. Hadley, K, Ried, M., and A. Rebertus 1991. The response of subalpine forests to spruce beetle outbreak in Colorado. Ecology, 71(1): 213-231.