Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings*

June 10–11, 2008
University of Northern British Columbia, Prince George, B.C.

Table of Contents

* **Editor's Note:** Abstracts, Popular Summaries, and Syntheses are published "as presented" at the Conference, and have not been peer-reviewed as part of the publication process. In the listing of Poster Abstracts/Popular Summaries, "O" indicates an Oral Poster presentation and "S" indicates Stand-alone Poster.

This conference was funded, in part, by the British Columbia Ministry of Forests and Range through the Forest Investment Account–Forest Science Program, the Mountain Pine Beetle Emergency Response Team, and the BC Rural and Remote Health Research Network.

Planning and presentation of the event was made possible through the collaboration of

Forest Investment Account – Forest Science Program
Forestry Innovation Investment
Mountain Pine Beetle Emergency Response Team
British Columbia Ministry of Forests and Range
British Columbia Ministry of Environment
Natural Resources Canada, Pacific Forestry Centre
First Nations Mountain Pine Beetle Initiative
BC First Nations Forestry Council
Council of Forest Industries
University of Northern British Columbia

Introduction

The mountain pine beetle (*Dendroctonus ponderosae* Hopkins) has infested and killed millions of hectares of lodgepole pine (*Pinus contorta* var. *latifolia*) in the central and southern interior of British Columbia in the past few years (9.2 million ha of red attack in 2006; 582 million m^3 of timber). The unprecedented magnitude of this infestation has generated many questions about the effect that the infestation and the resultant salvage harvesting will have on the environment and on the socio-economic fabric of British Columbia. This is especially true for First Nations' communities within the beetle-attacked areas as much of their cultural, social, and economic well-being is tied to the forests surrounding their communities.

The high-priority mountain pine beetle (MPB) stewardship research gaps and activities to address these gaps can be found in the Ministry of Forests and Range Mountain Pine Beetle Stewardship Research Strategy: Implementation Framework (***http://www.for.gov.bc.ca/hre/pubs/docs/mpbstrategy.pdf***). To address the stewardship information gaps, several programs at both the provincial and federal levels have been initiated over the last 5 years to provide funding for research on the MPB and its effects. Many of these studies concluded at the end of March 2008.

FORREX, in partnership with a number of agencies and organizations, presented the Mountain Pine Beetle: From Lessons Learned to Community-Based Solutions Conference to:

- provide researchers and others who have conducted MPB-related projects with a chance to share project results with the operational community and other researchers and to highlight lessons learned;
- generate new ideas and strategies for sustainable (cost-effective and socially/culturally adoptable) solutions; and
- explore what we have learned from the MPB infestation to date.

The conference "message" underpinned key ecological, cultural, and social questions, such as:

1. Will the forests and ecosystems continue to provide the economic benefits, traditional non-timber products, and ecological and cultural services that we are accustomed to and expect from our forests?
2. How do natural disturbances such as the MPB influence the dynamics of the ecosystems in which they occur, and by how much?
3. What will the future forests in the areas affected by the MPB look like?

Showcased at the conference were research and projects funded by the Forest Investment Account (e.g., Forest Science Program and Land-base Investment Program), the Forestry Innovation Investment MPB program, and the Federal Mountain Pine Beetle Program, as well as projects and strategies co-ordinated by the three Beetle Action Coalitions and the First Nations Mountain Pine Beetle Initiative. All of these areas are interconnected and it is imperative that information is shared as we work together to find solutions.

Ultimately, the goal of this conference was to highlight and share significant "lessons learned" from both First Nations and non-First Nations perspectives—what is the latest science, experiential, and traditional ecological knowledge telling us about the influence of the MPB as a disturbance agent on forested ecosystem dynamics? The changing dynamics of these ecosystems could affect the production of the products and services to which we have become accustomed. The conference explored the lessons learned from 5 years of research and other initiatives, which aimed to address the biological, environmental, and socio-economic questions and challenges associated with MPB infestation. This knowledge will help us better plan and manage our natural resources now and for the future.

Acknowledgements

The Conference Chair, Al Wiensczyk, offers sincere thanks to the myriad people and funding agencies who were instrumental in helping to organize and deliver this conference. Thanks specifically to Monty Locke, Rob Parisotto, Colene Wood, Jennifer Burleigh, Evelyn Hamilton, Kelly Osbourne, Allan Powelson, Patrick Daigle, Chris Ritchie, Dave Harrison, Brad Hawkes, Dan George, Zandra Ross, Gina Thomas, Steve Kozuki, Elizabeth Andersen, Nicole Balliet, Staffan Lindgren, Sandra Earle, and Audrey Faktor, as well as FORREX staff Gord Austin, Satnam Brar, Pedro Lara Almuedo, Don Gayton, Chris Hollstedt, Dan Orcherton, Todd Redding, Sandra Ramunno, Julie Schooling, Kathie Swift, and Albie Thomson. A special thank-you goes to my MPB project assistant, Jillian Merrick, for her support and assistance leading up to this conference. I would also like to thank all of the conference's plenary speakers, panel and concurrent session team members, and oral and stand-alone poster presenters.

We would also like to respectfully acknowledge the Lheidli T'enneh First Nation within whose traditional territory the conference was held.

PowerPoint presentations made available by presenters at the panel discussion "Management, risk assessment, and control strategies: What have we learned?" are accessible on the conference website at: ***http://www.forrex.org/program/forest/mpb_conference.asp?AreaPkey=19&Prg=false***

MOUNTAIN PINE BEETLE: FROM LESSONS LEARNED TO COMMUNITY-BASED SOLUTIONS CONFERENCE PROCEEDINGS

JUNE 10–11, 2008

University of Northern British Columbia, Prince George, B.C.

Conference Program

Tuesday, June 10, 2008

Welcome and Opening Speakers

The mountain pine beetle as an agent of forest disturbance
Phil Burton, Natural Resources Canada

Overview analysis of mountain pine beetle in British Columbia
Bill Bourgeois, New Direction Resource Management Ltd.

Mountain pine beetle through the First Nations lens
Dan George, First Nations Mountain Pine Beetle Initiative

Thematic Sessions (choose 2 of 3)

Theme 1 – Stand Dynamics
Lead: Kathie Swift, FORREX

Theme 2 – Biodiversity and Habitat
Lead: Patrick Daigle, B.C. Ministry of Environment

Theme 3 – Watersheds
Lead: Todd Redding, FORREX

Lunch

Thematic Sessions (choose 2 of 3)

Theme 4 – Mountain Pine Beetle Biology and Population Dynamics
Lead: Jennifer Burleigh, B.C. Ministry of Forests and Range

Theme 5 – Socio-economics
Lead: Dan Orcherton, FORREX

Theme 6 – First Nations' Cultural and Societal Values
Lead: Gina Thomas, First Nations Forestry Council

Summary and Reporting from Thematic Sessions

Panel Discussion

What are the future forests in areas affected by mountain pine beetle going to look like with and without human intervention? What are science, traditional knowledge, and experience telling us?
Moderator: Colene Wood

Panel Members: Sybille Haeussler (University of British Columbia); Ivan Tallio; Steve Kozuki (Council of Forest Industries)

Wednesday, June 11, 2008

Interactive Poster Presentation Sessions

See pages 1–3 for listings of oral and stand-alone posters presented in each theme.

Panel Discussion

Management, risk assessment, and control strategies: What have we learned?
Moderator: Steve Kozuki, Council of Forest Industries
Panel Members: Shawn Meisner (Tolko); Rod DeBoice* (MPB Response Team); Ken Day* (Alex Fraser Research Forest)*

Lunch

Thematic Sessions (choose 2 of 3)

Theme 7 – Silvicultural Treatment and Restoration Options
Lead: Allan Powelson and Kelly Osbourne, B.C. Ministry of Forests and Range

Theme 8 – Fibre Opportunities and Manufacturing
Lead: Rob Parisotto, Forestry Innovation Investment, and Albie Thomson, FP Innovations–Feric Division

Theme 9 – Fuel Loading and Fire Behaviour
Lead: Brad Hawkes, Pacific Forestry Centre

Panel Discussion

Will the forests and ecosystems continue to provide the economic benefits, traditional non-timber products, and ecological and cultural services that we are accustomed to and expect from our forests?
Moderator: Al Wiensczyk, FORREX
Panel Members: Greg Halseth (University of Northern British Columbia); Bryan Bogdanski (Pacific Forestry Centre)

Closing Remarks

Where do we go from here?
Ray Schultz

* Indicates that PDF versions of these panel members' PowerPoint presentations are available on the Conference website at: *http://www.forrex.org/program/forest/mpb_conference.asp?AreaPkey=19&Prg=false*

Popular Summary

The mountain pine beetle as an agent of forest disturbance

Philip J. Burton[1]

Presentation Abstract

Outbreaks of mountain pine beetle are evaluated as a generic disturbance agent, and comparisons are made with other forest disturbances such as wildfire, windthrow, and logging. A useful basis for comparison is the degree of disruption to the overstorey, understorey, and forest floor layers. Clear differences are observed in the impacts of bark beetles, fire, and windthrow, but there is overlap with various harvesting systems. Insects are selective in terms of the species or size of tree that is killed; this selectivity varies with stand composition, stand structure, and outbreak stage. The mountain pine beetle functions as part of larger natural disturbance regimes in western North America, which vary with climate and forest type. Outbreaks of many different insects occur throughout western Canada, with the relative role of fire and insects differing among ecoregions and over time. Beetle-killed stands may facilitate extreme fire behaviour and may be more susceptible to future burning. Large expanses of dead or removed trees also result in altered soil water balance and stream flows, disposing some sites to mass movement or flooding. All disturbances generate heterogeneity, with much of the value to biodiversity and ecosystem recovery depending on residual structure and biological legacies. The capacity for unassisted recovery and the value of each stand to timber supply, carbon balance, and habitat needs in a landscape context are relevant when considering salvage logging or forest rehabilitation. The future role of forest pests is expected to fluctuate in response to changes in climate and the altered composition and structure of western forests.

KEYWORDS: *disruption, disturbance agent, disturbance regime, insect selectivity, mountain pine beetle, unassisted recovery.*

Contact Information

1 Canadian Forest Service, and University of Northern British Columbia, Ecosystem Science and Management, 3333 University Way, Prince George, BC V2N 4Z9. Email: pburton@pfc.cfs.nrcan.gc.ca

Burton, P.J. 2008. The mountain pine beetle as an agent of forest disturbance. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):9–13. URL: *http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf*

Summary

An ecological disturbance is " . . . any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment" (White and Pickett 1985:6). As such, natural disturbances are the converse of stand development and succession, renewing forest stands and diversifying landscapes. Every disturbance has dual impacts: inducing mortality but facilitating regeneration; removing biomass but aiding nutrient cycling—essentially serving as an agent of both destruction and renewal. Because of an evolutionary history of repeated exposure to natural disturbances characteristic of a region (e.g., landslides, windthrow, fire, insect outbreaks), all ecosystems are adapted to recover and persist (not unchanged, but within some natural range of variability, NRV) after those disturbances (Figure 1a). Some intermediate level of disturbance frequency and intensity is typically required to maximize biological diversity within a landscape (Reice 2001). Whether due to human activities, invasive species, or climate change, disturbance can sometimes shift ecosystems beyond their NRV into alternative states from which they cannot readily recover. Considered "degraded" if caused by human activities, these ecosystems may still be functional and stable alternative states (Figure 1b).

Typically functioning as a "releasing" disturbance at endemic or background levels, full-scale population explosions by herbivorous forest insects can also serve as agents of wholesale stand mortality and renewal. Outbreaks of the mountain pine beetle can be described and evaluated as a generic disturbance agent, comparable to other forest disturbances such as wildfire, windthrow, and logging. None of these disturbances are homogenous in their effects, even within a single event. As proposed by Roberts (2007), a useful basis for site-to-site comparison is an assessment of the degree of mortality or disruption to the overstorey (mature tree layer), the understorey (tree seedlings and saplings, shrubs, and herbaceous vegetation), and the forest floor (duff and soil layers).

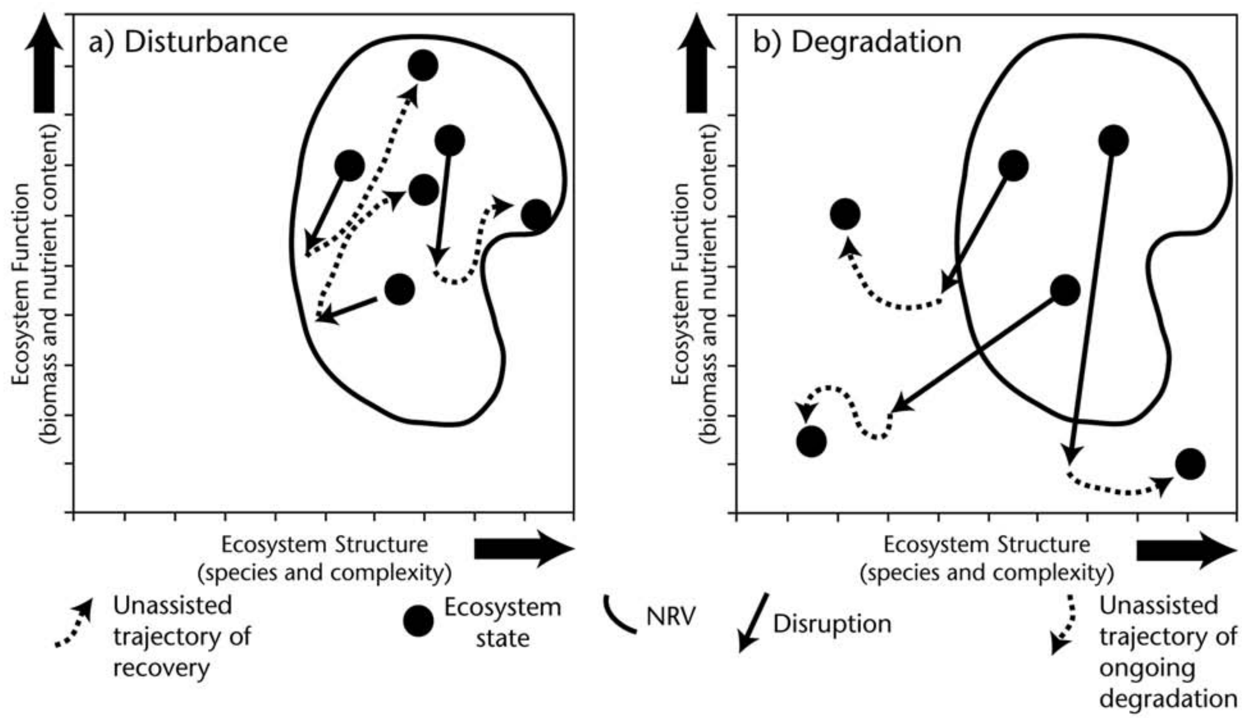

FIGURE 1. Schematic portrayal of ecosystem response to disturbance: (a) Under disturbance regimes to which an ecosystem is adapted, a disrupted ecosystem will typically return to a condition similar (but not identical) to its original condition, within some envelope we can recognize as the historical or natural range of variability (NRV). (b) Novel or persistent disturbances may push ecosystems into alternative states that do not return to the NRV envelope without assistance (Burton 2005).

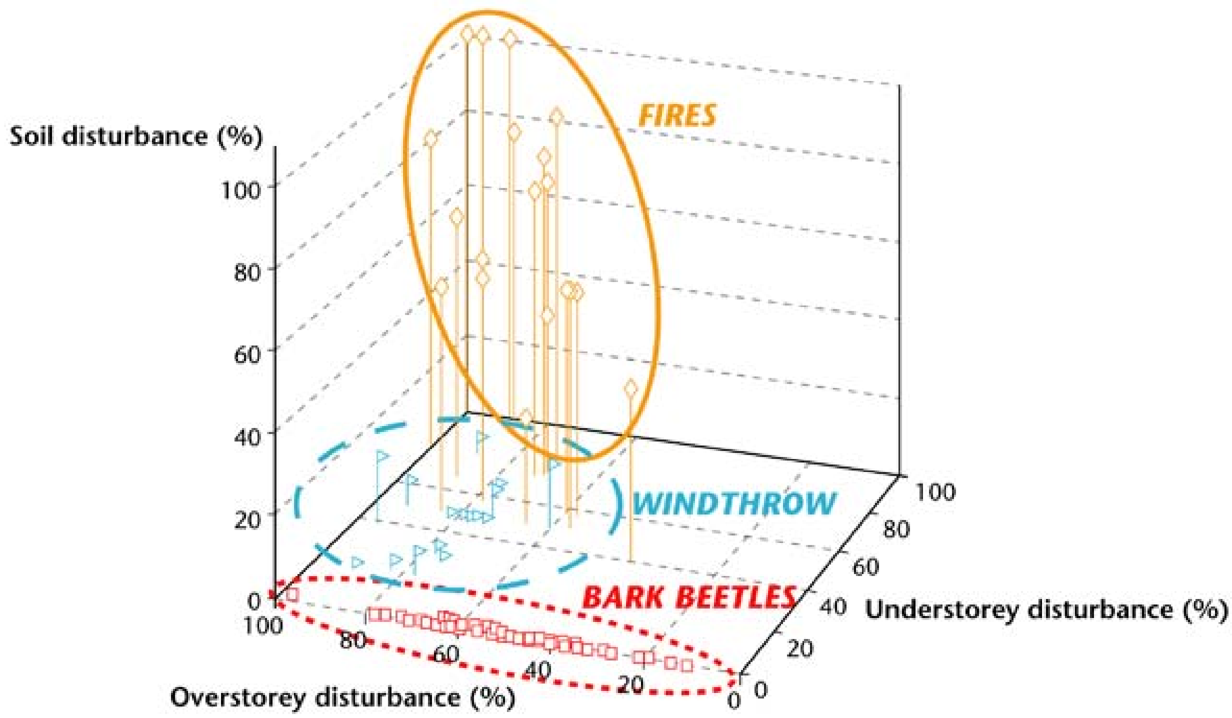

FIGURE 2. Levels of overstorey, understorey, and soil disturbance observed on sites affected by various natural disturbances in the Sub-Boreal Spruce moist cold (SBSmc) subzone, Bulkley and Nadina Forest Districts, west-central British Columbia.

Clear differences are observed in the impacts of bark beetles, fire, and windthrow, as bark beetles typically have only indirect effects on the understorey and the forest floor (Figure 2). There can be overlap of clearcut logging and alternative (partial cutting) harvesting systems with the range of variability encountered in natural disturbances, though less so in the case of insect outbreaks. By virtue of specific host requirements, insects tend to be very selective in the species (or, in the case of mountain pine beetle, the size) of tree that is attacked and killed. This selectivity varies with stand composition and structure and with outbreak stage (Figure 3).

The mountain pine beetle functions as part of larger natural disturbance regimes in western North America, which vary with climate and forest type. Large and small outbreaks of many different insects have been recorded in the forests of central British Columbia, and the relative role of fire differs dramatically among ecoregions and over the past few decades (Figure 4). Beetle-killed stands may facilitate more extreme fire behaviour and may be more susceptible to burning in the future. Large expanses of dead or removed trees due to any mortality agent also result in altered soil water balance and streamflows, further disposing some sites to seasonal flooding and mass movements (e.g., soil slumping).

All disturbances generate heterogeneity in habitat and microsites, with much of the value to biodiversity and ecosystem recovery depending on the residual structure and biological legacies left on site. The carbon in dead trees, fine organic matter, and soils resides in different pools of slow- or fast-decomposing organic matter, typically resulting in net CO_2 release until the ecosystem recovers. Policies, practices, and guidelines for salvage logging or forest rehabilitation after natural disturbances may wish to consider the capacity for unassisted post-disturbance recovery on a stand-by-stand basis, as well as the relative value of each stand to current and future timber supply, carbon balance, and habitat needs in a landscape context (Lindenmayer *et al.* 2008). The role of the mountain pine beetle and other forest pests is expected to fluctuate over the coming decades, in response to changes in climate and the altered composition and structure of western forests.

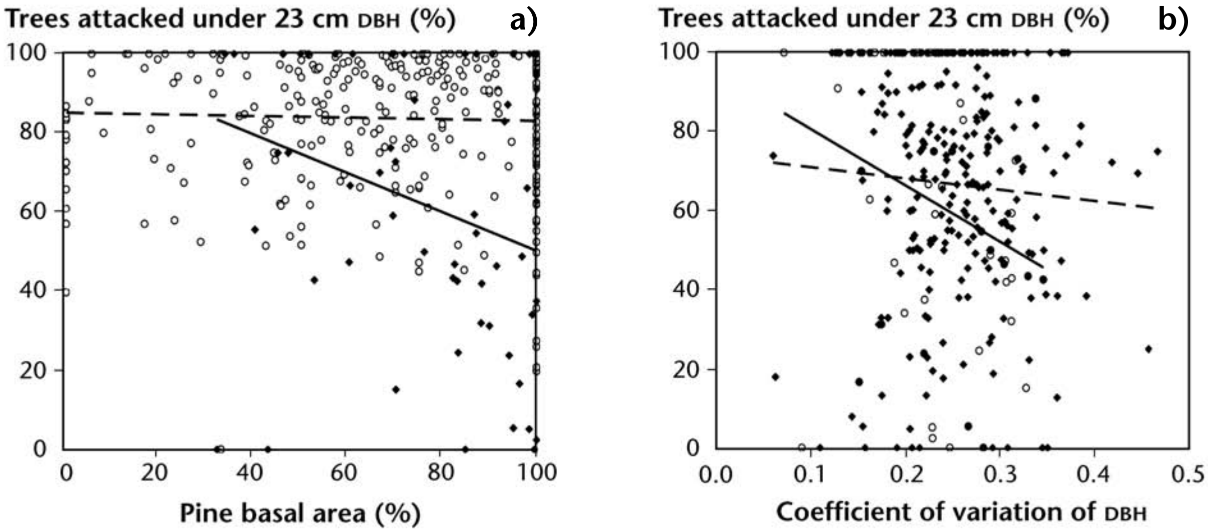

FIGURE 3. Sample plot data and linear regression lines fit for percentage of small (< 23 cm DBH) lodgepole pine trees attacked as related to: (a) the abundance of pine in the stand; or (b) variability in stand population structure as indicated by the coefficient of variation in DBH, during two phases of the current mountain pine beetle outbreak. Open circles and solid line illustrate the first, incipient phase, and diamonds and dashed line illustrate the second, full-outbreak phase of attack. Regression slopes are significantly different from zero at $p < 0.001$.

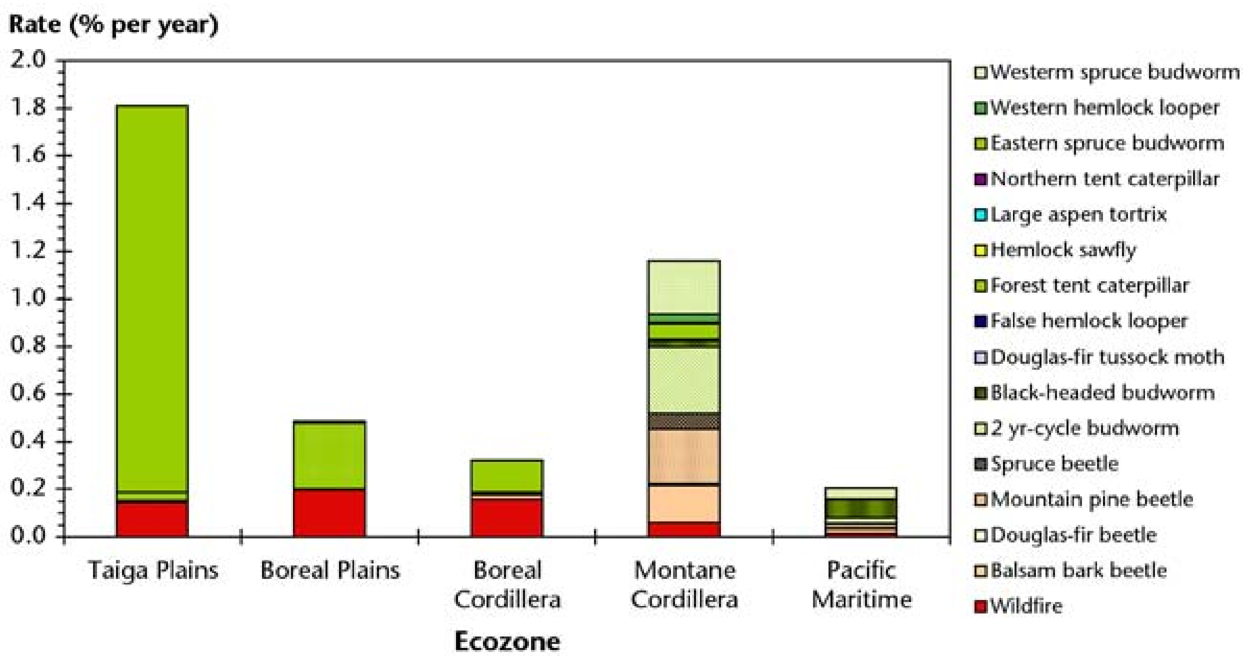

FIGURE 4. The mean area affected per year (as a percentage of forested area) from 1961 to 2000 by different fire and insect disturbance agents in different ecozones of British Columbia. Analysis is based on mapped records in the B.C. Natural Disturbance Database (Taylor 2007).

References

Burton, P.J. 2005. Ecosystem management and conservation biology. *In* Forestry handbook for British Columbia, Fifth edition. S.B. Watts and L. Tolland (editors). Faculty of Forestry, University of British Columbia, Vancouver, B.C. pp. 307–322

Lindenmayer, D.B., P.J. Burton, and J.F. Franklin. 2008. Salvage logging and its ecological consequences. Island Press, Washington, D.C.

Reice, S.R. 2001. The silver lining: The benefits of natural disasters. Princeton University Press, Princeton, N.J.

Roberts, M.R. 2007. A conceptual model to characterize disturbance severity in forest harvests. Forest Ecology and Management 242:58–64.

Taylor, S.W. 2007. British Columbia natural disturbance database. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, B.C. URL: ***http://cfs.nrcan.gc.ca/subsite/disturbance/home-accueil***

White, P.S. and S.T.A. Pickett. 1985. Natural disturbance and patch dynamics: An introduction. *In* The ecology of natural disturbance and patch dynamics. S.T.A. Pickett and P.S. White (editors). Academic Press, San Diego, Calif. pp. 3–13

Abstract

Overview analysis of mountain pine beetle in British Columbia

Bill Bourgeois[1]

Presentation Abstract

Recognition of the potential and experienced magnitude of the mountain pine beetle (MPB) infestation has been known for a decade. The governments of British Columbia and Canada have spent or committed $1 billion towards addressing issues related to this catastrophic event. They have also referred to a future combined commitment of another $1 billion over the next 10 years. An overview discussion of the impacts of the MPB on forest management, the economy, environment, non-timber forest products, communities, and the province is provided based on a literature review, augmented with comments from professionals. The actions to date, including funding allocations, research, monitoring and projections, forest management, environmental protection, and community resiliency are outlined. The broad gaps in knowledge and government policies are presented relative to achieving the goals of provincial and federal governments, First Nations, the forest industry, and communities. The lessons learned from the MPB infestation, as they relate to adapting to climate change in moving toward the future forest condition and building resilient communities, are presented as guidance to strategic and operational planning by forest managers, policy makers, researchers, and community advisors.

KEYWORDS: *actions, impacts, knowledge gaps, mountain pine beetle.*

Contact Information

1 New Direction Resource Management Ltd., 835 Strathaven Drive, North Vancouver, BC V7H 2K1.
Email: wwb@telus.net

Bourgeois, B. 2008. Overview analysis of mountain pine beetle in British Columbia. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):14. URL: *http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf*

Abstract

Mountain pine beetle through a First Nations lens

Dan George[1]

Presentation Abstract

A history of the First Nations Mountain Pine Beetle Initiative (FNMPBI) was outlined along with the First Nations political climate in British Columbia. The FNMPBI, the provincial government, and the First Nations Forestry Council all work together to assist the 103 First Nations residing in the province's mountain pine beetle impact zone. The FNMPBI has worked with the First Nations' communities using the Balanced Scorecard method in relation to the mountain pine beetle. This approach identified three important areas requiring attention: community protection, ecosystem stewardship, and sustainable economy. All underscored the overarching principle of engaging First Nations and protecting First Nations' cultural values. General principles for engaging First Nations were presented as well as the keys to reducing conflict with First Nations' communities.

KEYWORDS: *Balanced Scorecard, community protection, ecosystem stewardship, First Nations, mountain pine beetle, sustainable economy.*

Contact Information

1 Chief Executive Officer, First Nations Mountain Pine Beetle Initiative, 1044 Whenun Road, Prince George, BC V2K 5X8. Email: fdms@telus.net

George, D. 2008. Mountain pine beetle through a First Nations lens. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):15. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

The scene is set, the action begins, but what will happen next? Stand dynamics and the mountain pine beetle

Kathie Swift[1]

Abstract

Let us use Hamish Kimmins' often-presented view that the current state of our forest stands and their potential future outcomes can be better understood as "ecological theatre"—that the conditions we see today represent only one "scene" and the ecological "actors" in this play will shift in and out over time and space based on the events (mortality, regeneration, and growth) taking place. We also recognize that the play's original actors and the shifts that occur over time with these characters will depend on many site factors. Using this metaphor, we will examine the possible "alternative endings" that lodgepole pine stands affected by the mountain pine beetle may have as we look into the future based on their successional dynamics. Recognizing the complexity and infinite number of possible combinations that exist with lodgepole pine succession, our discussion focusses on four basic successional pathways. Using the research information generated over the past number of years, we explore the role the mountain pine beetle may have in shifting the actors over time.

Act 10 – Scene 14 (setting the stage for action in the epic thriller—*The Return of the Mountain Pine Beetle*): As the vast lodgepole pine forests of British Columbia grow in girth and enter their prime, the mountain pine beetle (always lurking in the background) seizes the opportunity to expand its presence in these forests and moves in for the kill . . . we know that there will be death and destruction, but how will it end?—ACTION!

KEYWORDS: *lodgepole pine, mountain pine beetle, regeneration, silvics, stand dynamics, succession.*

Contact Information

1 Early Stand Dynamics Extension Specialist, FORREX, c/o Council of Forest Industries, 360–1855 Kirschner Road, Kelowna, BC V1Y 4N7. Email: Kathie.Swift@forrex.org

Swift, K. 2008. The scene is set, the action begins, but what will happen next? Stand dynamics and the mountain pine beetle. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):17–23. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Introduction

Let us use Hamish Kimmins' often-presented view that the current state of our forest stands and their potential future outcomes can be better understood as "ecological theatre"—that the conditions we see today represent only one ecological "scene" and the ecological "actors" in this play will shift in and out over time and space based on the events (mortality, regeneration, and growth as determined by type and severity of disturbance) taking place (Kimmins 2007). We also recognize that the play's original actors and the shifts that occur over time with these characters will depend on many elements that function at various spatial and temporal scales. Using an "ecological theatre" metaphor, we examine the possible "alternative endings" that lodgepole pine stands affected by the mountain pine beetle (MPB) may have as we look into the future based on their successional dynamics. Recognizing the complexity and infinite number of possible combinations that exist with lodgepole pine succession, especially following a MPB disturbance of the current size, we focus our summary on the four basic successional pathways described by Pfister and Daubenmire (1975). We use the research information generated over the past number of years to explore the role the MPB may have in shifting these four stages and the actors over time. This paper is also based, in part, on presentations at the Mountain Pine Beetle: From Lessons Learned to Community-based Solutions conference held in Prince George, B.C., June 10–11, 2008. Other critical areas of consideration when dealing with MPB-affected stands, such as forest fire fuel management and biodiversity, were outlined by other conference presenters (see, for example, synthesis papers by Hawkes [page 77] and Lewis [page 24]).

Basic Principles of Stand Dynamics to Think About

Before going further, some of the terms and concepts that will be bandied about in this discussion require clarification. Many of these were presented in Oliver and Larson's book on *Forest Stand Dynamics* (Oliver and Larson 1996). For example, Oliver and Larson referred to "forest stand dynamics" as the changes in forest stand structure with time, including stand behaviour during and after disturbance. "Stand" refers to the spatially continuous group of trees and associated vegetation having similar structure and growing under similar soil and climatic conditions; the "structure" of the stand refers to the physical and temporal distribution of trees and other plants in a stand. When we consider the successional development of a lodgepole pine stand, factors such as site potential, existing composition and structure, serotiny and other regeneration factors, disturbance interactions, and climate (drought, climate changes) will all play a role in determining the pathway the stand will follow. However, we must also recognize that a stand and the structures which result from the MPB disturbance do not exist in isolation from broader, ecosystem-level processes. Interpreting stand-level observations as a way of predicting future stand-level conditions should be approached with caution. Stand dynamics is a complex topic. One way of processing this complexity is to visualize stands as ecological theatre. This allows us to better understand the concept that the group of trees or ecological actors found in the stand can remain or disappear depending on their response to disturbances that take place at differing spatial and temporal scales.

> *Using an "ecological theatre" metaphor, we examine the possible "alternative endings" that lodgepole pine stands affected by the mountain pine beetle may have as we look into the future based on their successional dynamics.*

When we look at lodgepole pine, a species with a large ecological amplitude (i.e., it grows from low to high elevation, from warm to cold temperatures, from relatively dry to wet conditions, and grows on most soil types; Fowells 1965) and that covers some 14 million ha in British Columbia, we can easily conclude that the stand dynamics taking place over its vast range are likely not the same. So how can we place stand dynamics and the influence of the beetle into context without making the discussion too complex, especially given that the successional consequences of disturbance are highly variable and that very little is known about how the beetle and fire interact within a stand and across the landscape to regulate the ecosystem as a whole (Shore *et al.* 2006)? One way is to view four possible ecological plays that are taking place on the land base where lodgepole pine is one of the major actors and see how the MPB may have changed the future role of lodgepole pine. Again, it is important to recognize that, given the complexity of the ecosystem, numerous potential differences may exist even between these four plays. This discussion is, therefore, an oversimplification of the reality of these systems.

Stand Dynamics of Lodgepole Pine Stands Affected by the Mountain Pine Beetle: Four Possible "Plays"

Stand Dynamics In Which Lodgepole Pine is a Minor Player in the Canopy

In this play, lodgepole pine grows in combination with other species such as trembling aspen and Douglas-fir. Lodgepole pine likely plays a smaller role under these "minor seral stand conditions" (Pfister and Daubenmire 1975) because the sites either provide good establishment conditions for other species, which outcompete the pine, or the stands are older and have lost lodgepole pine through succession. According to initial data, this stand type represents about 31% of the area attacked by MPB in the recent infestation (Burton 2006). When MPB enters the play as a disturbance agent and kills the pine component of this stand type, the pine is simply replaced by the other species growing with it. Lodgepole pine is shade-intolerant, limiting its ability to regenerate and compete successfully under the light conditions available in the residual stand. Therefore, this species likely exits the stage until favourable growing conditions allow it to re-enter.

Stand Dynamics In Which Lodgepole Pine is a Major Player in the Canopy

Another play sees lodgepole pine dominating the main canopy. In this scenario, however, an understorey of shade-tolerant species exists due to the prevailing site conditions. Some of these species (e.g., spruce and subalpine fir) likely established at the same time as the pine; others have continued to establish over time creating layers of poles, saplings, and seedlings (Burton 2008). In this play, the MPB's role is one of a thinning or understorey release agent, reducing stand density and the shading of pine to the benefit of the residual trees and understorey. These remaining live trees and advanced regeneration could provide some short-term and potentially longer-term relief to the reduction of local timber supply (Burton 2008). This play has therefore been the focus of much research investment dedicated to addressing the MPB infestation in the province's Interior. Data indicates that this stand type represents 40% or more of the forests affected by MPB (Burton 2006).

Although limited published data is available for the current MPB attack, past research suggests that the response of the residual understorey depends highly on the physiological condition of the advanced regeneration and its reaction to the stress of changes in light conditions and other forest health issues, especially as the standing dead pine begins to break apart and fall (Griesbauer and Green 2006). For example, faster-growing pine has for many years suppressed trees that germinated at the same time as the pine overstorey. As the canopy opens up, the ability of these trees to respond to the additional light, moisture, and nutrients depends on the amount and distribution of the photosynthetic material found in their crowns (Griesbauer and Green 2006). The same is true for stems that have established more recently; however, because the dead trees can still provide shade for 10–15 years (Shore *et al.* 2006), these younger, shade-tolerant stems may be more physiologically advantaged to adapt to the changing growing conditions and release (Griesbauer and Green 2006). Initial reports from our British Columbia research indicate that advanced regeneration of white, hybrid, and black spruce, as well as subalpine fir, is indeed releasing in both height and diameter as the dead pine canopy begins to open up (C. DeLong, B.C. Ministry of Forests and Range, pers. comm., 2008). In addition, the data indicates that distribution of the advanced regeneration found under these dead seral pine stands is variable—from clumpy to low densities depending on the stand and site conditions (Griesbauer and Green 2006). Largely unknown is the successional patterns and processes of stands that arise from advanced regeneration following large stand-releasing disturbances such as this MPB attack, although some information is becoming available (Dykstra and Braumandal 2006; Dordel *et al.* 2008). This knowledge gap still remains to haunt us as we try to determine the economic viability of these future forests and the communities they previously supported. Long-term monitoring to determine the future outcome of these types of stands will be a very important component of addressing this knowledge gap.

Stand Dynamics In Which Lodgepole Pine is the Only Major Player in the Canopy

Persistent

The final two plays see lodgepole pine playing a solo lead role, and according to available data, pine represent a minority (25.8%) of the forest area affected by MPB (Burton 2006). The first of these roles is somewhat similar to the one described for the previous play, although little evidence exists that pine is being replaced by shade-tolerant species. Lodgepole pine persists as the only tree species when seed sources of shade-tolerant species are inadequate or the site is poorly suited for other species (Shore *et al.* 2006). During the current MPB disturbance, the beetle has killed the majority of the pine, leaving odd individuals surviving under this "persistent" condition (Pfister and Daubenmire 1975). These individuals may have survived due to small size, exceptional genes (which have control over the phloem layer; Yanchuk *et al.* 2008), ideal microsite conditions, or unexplained luck (Burton 2008). These factors are also responsible for lodgepole pine survival in the other previously mentioned plays. However, the ability of these pure pine stands (with the majority of their healthy stems dead) to regenerate in the absence of fire is largely unknown. Unpublished observations in the Prince George area indicate that in many of these dead stands regeneration is not occurring after 10 years (C. DeLong, B.C. Ministry of Forests and Range, pers. comm., 2008). Research shows that seed viability is not a concern in the short term as the majority of lodgepole pine cones produced are serotinous and are considered discrete, closed units isolated from the tree and the environment as long as the serotiny is maintained (Kolotelo 2008). A bulletin released by the Ministry of Forests and Range suggests that seed in cones collected from trees dead for 10 years is still viable (Kolotelo 2008). Data also shows that dead trees are still standing 10–15 years after attack. So, will enough viable seed remain to take advantage of the additional light and (or) soil disturbance as the larger dead pine fall and create openings, or will the regeneration come from the smaller, living, possibly genetically inferior trees (Roe and Annan 1970)? Will cone serotiny play a role in determining regeneration success? If serotinous cones are dominant, will sufficient heat be created (i.e., while trees are standing, or on the forest floor when trees fall) to ensure these cones open and contribute to regeneration if viable seedbeds exist? Will these stands follow the pathway of those in southeastern British Columbia (the Flathead) where a pulse of regeneration took place 10–20 years after the infestation (Coates 2008)?

To further complicate matters, data also suggests that the smaller lodgepole pine growing under the canopy and pole-sized trees growing in the canopy are undergoing a secondary bark beetle attack (i.e., Ips; G. Newsome, B.C. Ministry of Forests and Range, pers. comm., 2007). Ips tends to attack standing dying or damaged lodgepole pine, but populations can also build up in windthrow and slash, posing a threat to healthy green trees adjacent to MPB-attacked stands (Henigman *et al.* 2001). Thus, the future regeneration supply for these sites is further reduced. Will grasses or shrubs, which may be present in the understorey and which will respond favourably to the increase in light, take over the growing space and further limit the ability of the next pine crop to establish? If lodgepole pine manages to re-establish, will these stands and the corresponding stand structure be as viable or as healthy as the previous one, or will these forests require a natural or prescribed burn (or undergo some other form of rehabilitation) to establish another vigorous lodgepole pine forest? Forests are resilient and will usually regenerate in some manner. However, in the absence of any further disturbance—natural or anthropogenic—long-term stand monitoring may be the only way to determine what these forests will look.

Climax

In the final play, lodgepole pine is the only actor—the only species capable of growing; consequently, it has managed to perpetuate itself in an uneven-aged stand condition. This type of pine stand is often found where soils hold limited moisture (Pfister and Daubenmire 1975), although patches of other species such as aspen may be found on specific microsites. One example of this scenario is lodgepole pine stands growing in the Chilcotin Plateau. In 2001, the Canadian Forest Service established a research project there to examine the effect of MPB on stand dynamics. The unique multi-age and size structure that exists on the plateau is a result of pine's ability to regenerate under its own canopy from past multiple MPB outbreaks and surface fires. Project results to date seem to indicate that MPB has attacked and killed the larger diameter classes releasing the understorey pine, which can vary in age from a few years to over 100 (Shore *et al.* 2006). The data also suggests that, even though pine can regenerate, the number of fires and MPB disturbances it is able to survive determines its long-term success (Hawkes 2006).

In 2008, the B.C. Ministry of Forest and Range asked the Canadian Forest Service to survey the plots for lodgepole pine dwarf mistletoe infections on the surviving stems during follow-up monitoring of the Chilcotin project (B. Hawkes, Canadian Forest Service, pers. comm., 2008). This dwarf mistletoe can cause stem breakage (through structural weakness produced by the swelling of the stem), reduced height and diameter growth, as well as reduced lumber recovery of the affected stems (Henigman *et al.* 2001) and is thus not considered desirable in lodgepole pine stands. Initial results from this forest health survey indicate that these stands are highly infected (B. Hawkes, Canadian Forest Service, and G. Newsome, B.C. Ministry of Forests and Range, pers. comm., 2008). This places the long-term growth and productivity of these stands into question, as well as their value and viability for lumber manufacturing. The follow-up monitoring also showed that aspen is now more of an actor on these sites. Unlike the previous two plays, the finale for this type of lodgepole pine stand is clearly based on its stand dynamics—an uneven-aged, multi-structured lodgepole pine stand continuing indefinitely. However, perhaps an alternative ending is again in store for this stand type with the declining incidence of surface fires (possibly due to the introduction of fire control laws in the early 1900s), lack of aboriginal burning, fire suppression activities, changing land use practices (Hawkes 2006), and the increasing presence of aspen in the play.

Effects of the Mountain Pine Beetle on Supporting Actors in this Ecological Theatre

We have discussed stand dynamics following MPB disturbance from the perspective of trees as the major actors. However, any play includes other actors in supporting roles. As we have seen, dead lodgepole pine can remain standing for 5–15 years. In their role as standing dead trees, these pine provide food and shelter for the birds and wildlife species inhabiting the area (DeLong *et al*. 2008). As the pine begin to break up and fall, increased sunlight and increased short-term water levels, which occur because the "pumps are no longer pumping," may create an environment that favours berry-producing shrubs over time—again supporting the other actors in the scene.

Many of these pine stands, and the resulting ground vegetation that forms part of the stand dynamics, also contribute to the food supply of the First Nations people living in the north, who gather the vegetation itself or hunt game that eats the fruit of this vegetation. The MPB significantly affects both food sources for these people. These effects can be positive or negative, but since a MPB outbreak of this magnitude is such an infrequent event, First Nations must adapt to the changing conditions to locate their food.

We cannot forget that fire is a key disturbance factor in lodgepole pine dynamics. The current MPB outbreak in northern British Columbia has resulted in many dead trees. As these trees begin to fall, the potential for fuel loading increases, especially if large numbers of dead trees fall during a relatively short period of time. This increase in fuel loading, both on the ground and as standing structures, should influence fire behaviour (Shore *et al*. 2006). Thus, it is again important that this disturbance agent is not viewed in isolation from other broader landscape disturbance features when considering stand dynamics following MPB.

What Information Do We Still Need?

What information is still outstanding as we look at stand dynamics and the MPB? Shore *et al*. 2006 provided the following summary of important knowledge gaps.

> *Little is known about the long-term post-epidemic development and growth of stands that have not been subjected to control measures. A sound understanding of the impacts of mountain pine beetle outbreaks on growth and yield of surviving trees in residual stands, regeneration, woody debris dynamics, and fire potential is needed for managers to make better decisions regarding stand management in the face of mountain pine beetle attacks. Specifically, the following knowledge gaps need to be addressed.*
>
> - *Factors affecting variation in stand depletion*
> - *Growth response of residual stands in different habitat types*
> - *Release of advance regeneration and establishment of new regeneration in stands representing different successional stages for lodgepole pine*
> - *More specific research on effect of mortality caused by mountain pine beetle on fire occurrence and intensity* (Shore *et al*. 2006:109)

To this list, we could add the following:

- The longer-term effect of MPB in persistent lodgepole pine stands without fire: what is the outlook for these stands if they don't burn?
- What is the effect of dwarf mistletoe on long-term productivity of climax lodgepole pine stands?
- What influence does changing stand dynamics have on wildlife species, especially those sensitive to the loss of large trees?

Summary

Lodgepole pine is an important actor in the forestry landscape of the Interior of British Columbia. This paper provides a brief summary of the possible future outcomes based on stand dynamics for only four of the potentially hundreds of combinations of MPB-attacked lodgepole pine stands that are now growing. Monitoring information suggests that regeneration of various species, including lodgepole pine, is taking place under the killed canopy; those that have burned are also regenerating primarily back to pine (DeLong *et al.* 2008). The current reality is that, because of the silvics of the species, pine is an important player. The more we can increase our understanding of the dynamics of the ecosystems in which it grows, the better able we may be to prevent a disturbance of this magnitude from happening again. We also cannot ignore its basic biology—pine maintains itself on the landscape through large numbers of trees, even though various pests and diseases generally reduce these numbers over time.

The current reality is that, because of the silvics of the species, pine is an important player.

Acknowledgements

This paper was written in support of a presentation and discussions that were part of the Stand Dynamics and Mountain Pine Beetle Session of the Mountain Pine Beetle: From Lessons Learned to Community-based Solutions that was held in Prince George, B.C., June 10–11, 2008. Information provided by Craig DeLong and Brad Hawkes made the presentation possible and workshop participation by Craig, Brad, and Alan Vyse added to the substance of the information gathered and summarized in this paper.

References

Burton, P. 2006. Restoration of forests attacked by mountain pine beetle: Misnomer, misdirected, or must-do? BC Journal of Ecosystems and Management 7(2):1–10. URL: ***http://www.forrex.org/publications/jem/ISS35/vol7_no2_art1.pdf***

_______. 2008. The potential role of secondary structure in forest renewal after mountain pine beetle. Canadian Silviculture Magazine (Summer). URL: ***http://www.canadiansilviculture.com/summer%2008/structure.html***

Coates, D. 2008. Evaluation of stand dynamics after a 25–30 year old MPB attack in the Flathead Region of south eastern British Columbia. FIA-FSP Project No. M085196. Final Technical Report.

DeLong, C. 2008. Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. Prince George B.C. Stand Dynamics and Mountain Pine Beetle Discussion Session.

DeLong, C., B. Heemskerk, and B. Rogers. 2008. Life after the mountain pine beetle. LINK 10(2):13. URL: ***http://www.forrex.org/publications/link/ISS52/vol10_no2_art8.pdf***

Dordel, J., M.C. Feller, and S.W. Simard. 2008. Effects of mountain pine beetle (*Dendroctonus ponderosae* Hopkins) infestations on forest stand structure in the Southern Canadian Rocky Mountains. Forest Ecology and Management 255:3563–3570.

Dykstra, P.R. and T.F. Graumandl. 2006. Historic influence of the mountain pine beetle on stand dynamics in Canada's Rocky Mountain parks. Canadian Forest Service, Pacific Forestry Centre, Victoria, B.C. Mountain Pine Beetle Initiative Working Paper 2006-15. URL: ***http://www.for.gov.bc.ca/hfd/library/documents/bib98279.pdf***

Fowells, H.A. 1965. Silvics of forest trees of the United States. U.S. Department of Agriculture, Washington, D.C. Agriculture Handbook No. 271.

Griesbauer, H. and S. Green. 2006. Examining the utility of advance regeneration for reforestation and timber production in unsalvaged stands killed by the mountain pine beetle: Controlling factors and management implications. BC Journal of Ecosystems and Management 7(2):81–92. URL: ***http://www.forrex.org/publications/jem/ISS35/vol7_no2_art9.pdf***

Hawkes, B. 2006. Interaction of fire and mountain pine beetle disturbance in the Chilcotin Plateau. *In* the Third International Fire Ecology and Management Congress Program Proceedings. November 13–17, 2006. San Diego, Calif.

_______. 2008. Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. Prince George B.C. Stand Dynamics and Mountain Pine Beetle Discussion Session.

Henigman, J., T. Ebata, E. Allen, J. Westfall, and A. Pollard. 2001. Field guide to forest damage in British Columbia. 2nd edition. Canadian Forest Service and

British Columbia Ministry of Forests, Victoria, B.C. Joint Publication No. 17. URL: *http://www.for.gov.bc.ca/hfp/publications/00198/*

Kimmins, H. 2007. Presentation at the ForestLeadership Sustainability for Success 2007 Conference. May 9, 2007. Vancouver, B.C.

Kolotelo, D. 2008. Lodgepole pine cone collections. B.C. Ministry of Forests and Range, Tree Improvement Branch, Victoria, B.C. Mountain Pine Beetle Seed Planning Bulletin No. 05. URL: *http://www.for.gov.bc.ca/hti/pinebeetle/Pli_Bulletin05.pdf*

Oliver, C.D. and B.C. Larson. 1996. Forest stand dynamics. John Wiley & Sons, New York, N.Y.

Roe, A.L. and G.D. Amman. 1970. The mountain pine beetle in lodgepole pine forests. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, Utah. General Technical Report INT-71.

Pfister, R.D. and R. Daubenmire. 1975. Ecology of lodgepole pine (*Pinus contorta* Douglas). *In* Management of lodgepole pine ecosystems: Symposium proceedings, October 9–11, 1973, Pullman, Wash. D.M. Baumgartner (editor). Washington State University Cooperative Extension Service, Pullman, Wash. pp. 27–46.

Shore, T.L., L. Safranyik, B.C. Hawkes, and S.W. Taylor. 2006. Effects of the mountain pine beetle on lodgepole pine stand structure and dynamics. *In* The mountain pine beetle: A synthesis of biology, management, and impacts on lodgepole pine. L. Safranyik and B. Wilson (editors). Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, B.C. pp. 95–114.

Yanchuk, A.D., N. Ukrainetz, and K.F. Wallin. 2008. Genetic variation of attack and resistance in lodgepole pine to mountain pine beetle. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. BC Journal of Ecosystems and Management 9(3):148. URL: *http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf*

Thematic Session Synthesis

Mountain pine beetle, wildlife habitat, and biodiversity: Lessons learned and future challenges

Doug Lewis[1]

Abstract

Although the current mountain pine beetle (MPB) outbreak is unusually widespread and severe, large, episodic insect events have likely been a natural recurring phenomenon in the pine-dominated landscapes of British Columbia. Thus, wildlife species and ecosystems should be relatively well adapted to recover following these types of disturbances. However, the effects of salvage harvesting on wildlife and biodiversity raises concerns as it removes or alters post-disturbance structural legacies and thus affects the severity and duration of impacts and the timing of recovery.

From this experience, two key lessons have emerged: (1) MPB-infested forests continue to provide wildlife habitat and the role of non-salvaged forests should be considered in achieving wildlife and biodiversity conservation objectives in the future; (2) Comprehensive landscape-level planning can help to mitigate the spatial and temporal effects of salvage harvesting and to balance wildlife and biodiversity with social and economic objectives. With the ongoing modification of forested landscapes through human activities and natural disturbances, and the uncertain future effects of climate change, lessons will be critical to ensure future wildlife habitat and biodiversity conservation.

KEYWORDS: *biodiversity, mountain pine beetle, salvage harvesting, wildlife habitat.*

Contact Information

1 Mountain Pine Beetle Specialist, B.C. Ministry of Environment, 1259 Dalhousie Drive, Kamloops, BC V2C 5Z5.
Email: Doug.W.Lewis@gov.bc.ca

Lewis, D. 2008. Mountain pine beetle, wildlife habitat, and biodiversity: Lessons learned and future challenges. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):24–32. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Introduction

The mountain pine beetle (MPB; *Dendroctonus ponderosae*) has been a leading wildlife management and biodiversity conservation issue in the Interior of British Columbia for more than 10 years. In this time, concern has been expressed over potential negative impacts to wildlife and biodiversity with the spread of the infestation and extensive salvage harvesting (Drever and Hughes 2001; Eng 2004). The legacy of the MPB outbreak and our management response will be a landscape far different from that which prevailed before the infestation. The resulting landscape condition will continue to influence resource management decisions well beyond the completion of the infestation and will present resource managers with increasing challenges to conserve wildlife habitat and biodiversity in the years to come. Consequently, it would be prudent to reflect on lessons learned from this experience.

The current MPB outbreak provides an opportunity to examine the efficacy of wildlife and biodiversity conservation strategies in the context of extreme natural disturbances. Such insight will be invaluable if even the most optimistic climate change projections unfold. These projections forecast rapid extensive change due to natural disturbances that may become increasingly frequent, severe, or extensive (Spittlehouse 2008). The lessons learned from this experience will be of particular importance in developing long-term conservation strategies that accommodate natural disturbance and ongoing human resource extraction and yet still achieve wildlife and biodiversity objectives. Although scientific findings from the MPB outbreak are only beginning to become available, they will provide invaluable scientific support for management situations well beyond the life of MPB-affected forests as attention shifts to climate change.

Focussing on wildlife habitat and biodiversity, this paper reviews knowledge gained from the combined effects of the MPB outbreak and our management responses to it, and condenses this information into key lessons learned. It is not intended to be a comprehensive review of existing research of MPB effects on wildlife habitat and biodiversity, as the published literature and the many reports are far too extensive to summarize. Readers are encouraged to explore the literature as it pertains to their management issues and to contact the research scientists or managers who are directly involved for specific detail. This paper is also based, in part, on discussions at the Mountain Pine Beetle: From Lessons Learned to Community-based Solutions conference held in Prince George, B.C., June 10–11, 2008. Other conference presenters outlined additional critical areas of consideration when dealing with MPB-affected stands, such as stand dynamics, watersheds, and forest fire fuel management (see, for example, synthesis papers by Swift [page 17], Redding *et al.* [page 33], and Hawkes [page 77]).

The current mountain pine beetle outbreak provides an opportunity to examine the efficacy of wildlife and biodiversity conservation strategies in the context of extreme natural disturbances.

The Mountain Pine Beetle Outbreak: Unnatural or Unusual?

Mountain pine beetle outbreaks in British Columbia's Interior are natural ecological phenomena—historic evidence of large outbreaks exist dating from the 1890s to the present day (Wood and Unger 1996; Alfaro *et al.* 2004; Taylor and Carroll 2004). These outbreaks have varied in size with large cyclic infestations corresponding to host susceptibility and climatic conditions (Shore and Safranyik 1992; Alfaro *et al.* 2004). Historic evidence shows outbreaks were often spatially concentrated and the severity of mortality mixed, ranging from low to severe attacks (Wood and Unger 1996; Taylor and Carroll 2004). The unusual severity and magnitude of the current outbreak, however, is likely a result of:

- high levels of susceptible pine forest, initiated by extensive wildfires (anthropogenic and natural ignitions) in the 1860s to 1920s;
- wildfire suppression; and
- recent warming climatic conditions favouring the beetle rather than the host tree's defensive mechanisms (Carroll *et al.* 2004).

So, although the current MPB outbreak is unusually large based on historic records, the effects of such large beetle outbreaks on pine-dominated ecosystems are not unnatural or without precedent.

The historic evidence of large, episodic insect outbreaks suggests insect mortality plays a significant role in forest stand dynamics in pine-dominated forest ecosystems (see Hawkes *et al.* 2004 for more detail; see Wong *et al.* 2003 for a review of pine-dominated ecosystems in British Columbia). Although lodgepole pine is often known as a seral species, successive MPB attacks can develop pine stands with an uneven-aged structure (DeLong and Tanner 1996; Hawkes *et al.* 2004). As a seral overstorey species, mortality of pine trees can promote a growth response in the non-pine conifer understorey[1] leading to a gradual transition to a non-pine climax forest community (Hawkes *et al.* 2004). Under either circumstance, MPB mortality can promote the development of complex forest structure, long-term structural legacies (live and dead standing and downed wood), and diverse vegetation communities (Dykstra and Braumandl 2006; Forest Practices Board 2007).

The Inevitability of Death: Wildlife and Biodiversity in Pine-dominated Forest Ecosystems

From a wildlife and biodiversity perspective, natural disturbances affect forest structure and the availability habitat elements spatially and temporally (Spies 1997). Ecosystems that experience relatively frequent, large, and severe disturbances, such as many of the lodgepole pine-dominated ecosystems in British Columbia, will develop fewer old and mature forests (B.C. Ministry of Forests and B.C. Ministry of Environment 1995). Consequently, wildlife species reliant on old-forest attributes (i.e., large old snags or abundant coarse woody debris) will be less abundant in these ecosystems, and most species should be relatively well adapted (Bunnell 1995; Perry and Amaranthus 1997). For example, in a review of the potential response of 182 forest-dwelling terrestrial vertebrates to MPB, Bunnell *et al.* (2004) noted few species prefer and none are restricted to pine-dominated forest types; however, most (65%) will react positively to the changes in the forest canopy due to MPB mortality. Where consecutive disturbances occur within the normal recovery time following a disturbance (such as post-disturbance salvage harvesting), novel ecosystems may emerge in which species are maladapted to the resulting ecosystem condition (Paine *et al.* 1998).

The extent of MPB effects on wildlife and plant species will depend on the severity of attack, the overstorey and understorey tree species composition, ecosystem type, and the landscape context (Chan-McLeod 2006). These factors influence the level of "biological legacies"—live and dead elements of the pre-disturbance forest structure that remain and that allow forest-dependent species to persist or re-establish following disturbance (Foster *et al.* 1998; Franklin *et al.* 2000; Lindenmayer and Franklin 2002). Forests infested with MPB leave significant intact biological legacies including: standing and downed dead wood, live "non-attacked" pine, and non-pine overstorey and understorey trees. Consequently, even in severely attacked stands, the effects of the overstorey tree mortality are often less severe or immediate compared to other disturbances such as wildfire.

Forests recently infested by MPB provide a good example of the gradual effects of beetle disturbance on the availability of habitat elements. Both live and recently killed trees that retain foliage continue to provide nest trees, forage, and cover from predators for forest-dependent wildlife such as red squirrel and flying squirrel (Stone 1995; Steventon 2006). Persistence of these prey species in infested stands will continue to attract avian predators such as northern goshawk and grey owl, or small forest carnivores such as ermine, marten, or fisher.

Recently attacked forests also provide a relatively immediate influx of resources to wildlife species that rely on disturbance events for forage and creation of habitat elements, such as dead and decaying trees (Chan-McLeod 2006). Recently killed trees are host to bark beetles, woodborers, and saphrophytic insects that provide an increase in food supply for avian species, such as the three-toed woodpecker and black-backed woodpecker (Steeger and Dulisse 1997; Steeger and Hitchcock 1998; Martin *et al.* 2006). However, the severity of the infestation can affect the duration of the food supply and the availability of habitat elements (Chan-McLeod 2006). Where attack levels are more moderate, the supply of insects and recruitment of dead trees are more gradual such that some bird species continue to use beetle-infested forests for several years (Bull 1983).

As beetle-infested trees die, break, or fall down, they continue to alter habitat structure and the availability of

[1] Information on understorey composition and density in various biogeoclimatic zones can be found in Coates *et al.* (2006) or Vyse *et al.* (2007).

habitat attributes for many wildlife species. Defoliated, broken, and fallen pine trees allow solar radiation to reach the forest floor, or free-up water in moisture-limited ecosystems, resulting in a forest understorey shrub and forb response and release of understorey conifers. The downed woody debris increases forest floor structure providing improved habitat for small mammal species such as red-backed voles (Sullivan *et al.* 2000). In addition, structural components within the regenerating stand (e.g., piles of coarse woody debris) provide cover and subnivean access for species such as marten and fisher that forage for mice and voles in the winter (Gyug 1994). Over time, tree mortality affects vertical and horizontal stratification and structural complexity of a stand and can result in more suitable habitat conditions for marten than would be otherwise present in a live pine-dominated forest or a stand that has been clearcut and planted (Huggard 2007).

The Effects of Mountain Pine Beetle Salvage Harvesting on Wildlife and Biodiversity

Wildlife and biodiversity may be more greatly affected by post-disturbance or salvage harvesting of MPB-infested forests than by the beetle itself (Bunnell *et al.* 2004). By removing or altering most of the remaining biological legacies, salvage harvesting following a natural disturbance generally represents an incremental additive disturbance to an already vulnerable ecosystem. (See Lindenmayer *et al.* [2008] or Lindenmayer *et al.* [2004] for more detailed information on the various ecological consequences of salvage harvesting following large-scale natural disturbance.) Some of the key impacts of salvage harvesting in beetle-infested stands on wildlife and plant species include the following.

- Short-term immediate habitat loss or alteration. Salvage harvesting can reduce the availability of existing habitat attributes, such as live non-pine trees, that maintain habitat conditions allowing forest-dependent species to persist or recover immediately following MPB attack.
- Loss of resources that have been added to the site due to the MPB infestation. When trees are salvage-logged, an immediate loss of beetles occurs (a forage resource for species such as woodpeckers) as well as the loss of standing snag trees that can provide nest, roost, or foraging trees for wildlife.
- Long-term habitat alteration. Salvage harvesting and reforestation can result in shifts in tree species composition and reduced structural complexity in regenerating forests. Broad-scale implementation of these practices can result in homogeneous landscapes with reduced structure, increasing susceptibility to future disturbance, and potentially failing to meet habitat requirements for many species (Chan-Macleod and Bunnell 2004).

Although the loss of biological legacies can increase the likelihood of negative effects to wildlife habitat and biodiversity, careful planning of salvage operations and retention of structural attributes at the time of harvesting can reduce or mitigate some of these effects (Bunnell *et al.* 2004; Eng 2004; Lindenmayer *et al.* 2004; Klenner 2006; Lindenmayer *et al.* 2008). Guidance documents suggest:

- increasing retention levels and sizes of retention patches as cutover opening size increases,
- focussing salvage on forests with higher proportions of pine, and
- avoiding riparian zones and increasing riparian buffers (Bunnell *et al.* 2004; Eng 2004; Snetsinger 2005).

In addition, the landscape context (e.g., the extent of existing and potential salvage, and the amount and characteristics of other forest types in the surrounding landscape) influences the potential risk of negative effects on wildlife and biodiversity. Hence, landscape- and stand-level retention levels may need to be increased where higher proportions of the timber harvesting land base are affected by MPB (Klenner 2006; Klenner and Lewis 2007).

In British Columbia, ongoing research shows evidence of the effectiveness of forest retention at maintaining habitat attributes for forest-dependent species. For example, the relative abundance of species such as flying squirrel and red squirrel increases with increasing tree retention following harvesting (Herbers and Klenner 2007). The abundance of red and flying squirrel in managed stands with retained trees may be equivalent to mature forests 20–30 years after harvest (Sullivan *et al.* 2000; Sullivan and Sullivan 2001; Sullivan *et al.* 2008). Species such as marten that are sensitive to the loss of mature forest structure through forest harvesting (Thompson and Harestad 1994) will continue to use disturbed forests with residual structure as has been seen following other insect outbreaks (Payer and Harrison 2000) or following harvesting with increased forest retention (Fuller and Harrison 2005). Marten may continue to forage for mice and voles in harvesting debris piles in logged areas (Gyug 1994). Often, structural retention will have far greater dividends for wildlife and biodiversity several years or decades following harvesting than at the time of harvest (Klenner 2006). As human activities and natural disturbances continue to modify British Columbia's forested landscape, retention of mature and old-forest attributes during harvesting will become increasingly important for wildlife and biodiversity conservation (Franklin *et al*. 1997; Carey 2000).

Lessons Learned

So, what have we learned after 10 years' experience with the MPB infestation? Consistent with existing research findings, I believe there are two key messages.

1. If we are concerned about conserving wildlife habitat and biodiversity, then we need to manage the impacts of salvage harvesting and related effects. The MPB infestation is a natural disturbance, and although unusually large and severe, the effects on wildlife habitat and biodiversity are not unnatural. Species and ecosystems are well adapted to respond to changes in habitat elements resulting from natural disturbances. However, salvage harvesting removes or alters post-disturbance legacies that, in turn, create differences in the spatial pattern and intensity of effects on wildlife habitat and the timing of habitat recovery. These changes may have long-lasting implications on species persistence or survival (Hobson and Schieck 1999).

   Resource managers and the public must realize that MPB-infested forests are not dead—we should reconsider the human desire to "do something" without clear objectives and an evaluation of tradeoffs and consequences just because we perceive that forest values are lost (see Burton 2006). Although infested stands may become less valuable for some species for a period of time, left alone these forests can continue to play an important ecological role. We should not ignore these ecological contributions. Decisions to retain, salvage-log, or rehabilitate MPB-infested stands will have different long-term ecological, social, and economic consequences. These consequences should be considered in advance of conducting further salvage operations or shifting harvest to green stands.
2. If we are concerned about mitigating the negative effects of salvage harvesting on wildlife and biodiversity, then careful planning is essential. Although society demands that we recover some economic losses following natural disturbance, this should not be done at the expense of other land use objectives. The same level of detail and technical rigour used to plan timber extraction should be applied to wildlife management, biodiversity conservation, and other land use objectives such as recreation or visual resource management.

   A multitude of strategic initiatives (e.g., Mountain Pine Beetle Action Plan; First Nations Mountain Pine Beetle Initiative) identify the need to incorporate wildlife habitat objectives and biodiversity conservation in our MPB response. For our operational response to meet multiple objectives, co-ordinated multi-stakeholder landscape planning needs to be based on sound science and risk management principles; largely, this planning is still not being done (Klenner and Lewis 2007). In the future, comprehensive land use planning will be critical to ensure wildlife habitat, biodiversity, and other non-timber objectives are addressed as we experience new demands for wood fibre, increased pressure from non-forestry sectors (e.g., energy production), and uncertainty about climate change effects on natural disturbances.

The Road Ahead . . .

The legacy of the MPB infestation will be rapid landscape change. In most cases, lessons will be learned too late to be used in response to the present MPB outbreak. However, our current forest management actions will affect the trajectory of forested landscapes over the coming decades, if not centuries. Consequently, the greatest benefit of this experience to wildlife habitat management and biodiversity conservation will be how we use this information as we address emerging forest management issues such as climate change. If the most significant climate change effects are expressed as more frequent, severe, or extensive natural disturbances (Spittlehouse 2008), then, much like MPB, most wildlife species will be well adapted to these types of habitat changes. There is little we can do to assist some species to "adapt" to an increased loss of habitat or to immediately restore lost habitat conditions. The processes that develop desired habitat attributes, such as large standing snags and dead wood, require time. Thus, one climate change adaptation strategy may be to manage the impact of human actions so that we do not impede the continuation of natural processes that develop these desired habitat attributes. To this extent, the adaptation "toolbox" is relatively small and requires forest policy and management actions related to the retention of mature forest structure during harvest and to the amount and design of forest reserves (Bengtsson *et al.* 2003; Wilson and Hebda 2008). Because mature forest reserves will continue to be susceptible to natural disturbance, we must conserve more to get less. Increased reserve areas and mature forest recruitment strategies may be required to offset losses from natural disturbance (Klenner *et al.* 2000). Given the recent rate of change on the land base, and a forecasted increase in the rate of landscape change, conserving wildlife and biodiversity in this province will require evaluation of both our forest management practices and our beliefs about the important roles of natural disturbances in forest ecosystems.

Given the recent rate of change on the land base, and a forecasted increase in the rate of landscape change, conserving wildlife and biodiversity will require evaluation of both our forest management practices and our beliefs about the important roles of natural disturbances in forest ecosystems.

Acknowledgements

I am grateful to Patrick Daigle, Walt Klenner, Chris Ritchie, and Kirk Safford for comments on earlier drafts of this article. I would also like to thank the following people for their assistance in providing information for the concurrent session and background information for this document: Harold Armleder, Patrick Daigle, Walt Klenner, Kathy Martin, Chris Ritchie, Kirk Safford, Dale Seip, Michael Stalberg, Doug Steventon, and Ted Zimmerman.

References

Alfaro, R.I., R. Campbell, P. Vera, B. Hawkes, and T.L. Shore. 2004. Dendrological reconstruction of mountain pine beetle outbreaks in the Chilcotin plateau of British Columbia. *In* Mountain pine beetle symposium: Challenges and solutions, October 30–31, 2003, Kelowna B.C. T.L. Shore, J.E. Brooks, and J.E. Stone (editors). Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, B.C. Information Report BC-X-399. pp. 245–256.

Bengtsson, J., P. Angelstam, T. Elmqvist, U. Emanuelsson, C. Folke, F. Moberg, and M. Nystrom. 2003. Reserves, resilience, and dynamic landscapes. Ambio 32(6):389–396.

British Columbia Ministry of Forests and B.C. Ministry of Environment. 1995. Biodiversity guidebook. Forest Practices Code of British Columbia, Victoria, B.C.

Bull, E.L. 1983. Longevity of snags and their use by woodpeckers. *In* Snag habitat management: Proceedings of the symposium. J.W. Davis, G.A. Goodwin, and R.A. Ockenfels (technical coordinators). U.S. Department of Agriculture Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo. General Technical Report RM-99. pp. 64–66.

Bunnell, F.L. 1995. Forest-dwelling vertebrate faunas and natural fire regimes in British Columbia: Patterns and implications for conservation. Conservation Biology 9(3):636–644.

Bunnell, F.L., K.A. Squires, and I. Houde. 2004. Evaluating the effects of large-scale salvage logging for mountain pine beetle on terrestrial and aquatic vertebrates. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, B.C. Mountain Pine Beetle Initiative Working Paper 2004-2.

Burton, P.J. 2006. Restoration of forests attacked by mountain pine beetle: Misnomer, misdirected, or must-do? BC Journal of Ecosystems and Management 7(2):1–10. URL: *http://www.forrex.org/publications/jem/ISS35/vol7_no2_art1.pdf*

Carey, A.B. 2000. Effects of new forest management strategies on squirrel populations. Ecological Applications 10(1):248–257.

Carroll, A.L., S.W. Taylor, J. Regniere, and L. Safranyik. 2004. Effects of climate change on range expansion by the mountain pine beetle in British Columbia. *In* Mountain pine beetle symposium: Challenges and solutions, October 30–31, 2003, Kelowna B.C. T.L. Shore, J.E. Brooks, and J.E. Stone (editors). Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, B.C. Information Report BC-X-399. pp. 223–232.

Chan-McLeod, A.C.A. 2006. A review and synthesis of the effects of unsalvaged mountain-pine-beetle-attacked stands on wildlife and implications for forest management. BC Journal of Ecosystems and Management 7(2):119–132. URL: ***http://www.forrex.org/publications/jem/ISS35/Vol7_no2_art12.pdf***

Chan-Mcleod, A.C.A. and F.L. Bunnell. 2004. Potential approaches to integrating silvicultural control of mountain pine beetle with wildlife and sustainable management objectives. *In* Mountain pine beetle symposium: Challenges and solutions, October 30–31, 2003, Kelowna B.C. T.L. Shore, J.E. Brooks, and J.E. Stone (editors). Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, B.C. Information Report BC-X-399. pp. 267–277.

Coates, K.D., C. DeLong, P.J. Burton, and D.L. Sachs. 2006. Abundance of secondary structure in lodgepole pine stands affected by mountain pine beetle. Report to the Chief Forester, August 2006.

DeLong, S.C. and D. Tanner. 1996. Managing the pattern of forest harvest: Lessons from wildfire. Biodiversity and Conservation 5:1191–1205.

Drever, R. and J. Hughes. 2001. Salvaging solutions: Science-based management of BC's pine beetle outbreak. David Suzuki Foundation, Vancouver, B.C.

Dykstra, P.R. and T. Braumandl. 2006. Historic influence of the mountain pine beetle on stand dynamics in Canada's Rocky Mountain parks. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, B.C. Mountain Pine Beetle Initiative Working Paper 2006-15.

Eng, M. 2004. Forest stewardship in the context of large-scale salvage operations: An interpretation paper. B.C. Ministry of Forests, Victoria, B.C. Technical Report No. 019. URL: ***http://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr019.pdf***

Forest Practices Board. 2007. Lodgepole pine stand structure 25 years after mountain pine beetle attack. Victoria, B.C. Special Report FPB/SR/32.

Foster, D.R., D.H. Knight, and J.F. Franklin. 1998. Landscape patterns and legacies resulting from large, infrequent forest disturbances. Ecosystems 1:497–510.

Franklin, J.F., D. Lindenmayer, J.A. MacMahon, A. McKee, J. Magnsun, D.A. Perry, R. Waide, and D. Foster. 2000. Threads of continuity. Conservation Biology in Practice 1:8–16.

Franklin, J.F., D.R. Berg, D.A. Thornburgh, and J.C. Tappeiner. 1997. Alternative silvicultural approaches to timber harvesting: Variable retention harvest systems. *In* Creating a forestry for the 21st century: The science of ecosystem management. K.A. Kohm and J.F. Franklin (editors). Island Press, Washington, D.C. pp. 111–139.

Fuller, A.K. and D.J. Harrison. 2005. Influence of partial timber harvesting on American martens in north-central Maine. Journal of Wildlife Management 69(2):710–722.

Gyug, L.W. 1994. Wildlife use of logging debris piles in clearcuts. B.C. Ministry of Environment, Penticton, B.C. Unpublished report.

Hawkes, B., S. Taylor, C. Stockdale, T. Shore, R.I Alfaro, R. Campbell, and P. Vera. 2004. Impact of mountain pine beetle on stand dynamics in British Columbia. *In* Mountain pine beetle symposium: Challenges and solutions, October 30–31, 2003, Kelowna B.C. T.L. Shore, J.E. Brooks, and J.E. Stone (editors). Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, B.C. Information Report BC-X-399. pp. 177–195.

Herbers, J. and W. Klenner. 2007. Effects of Logging pattern and intensity on squirrel demography. Journal of Wildlife Management 761(8):2655–2663.

Hobson, K.A. and J. Schieck. 1999. Changes in bird communities in boreal mixedwood forest: Harvest and wildfire effects over 30 years. Ecological Applications 9(3):849–863.

Huggard, D.J. 2007. Mountain pine beetle and salvage effects on pine marten in the Fly Hills area. B.C. Ministry of Environment, Kamloops, B.C. Unpublished report.

Klenner, W. 2006. Retention strategies to maintain habitat structure and wildlife diversity during the salvage harvesting of mountain pine beetle attack areas in the Southern Interior Forest Region. B.C. Ministry of Forests and Range, Southern Interior Forest Region, Forest Science Program, Kamloops, B.C. Extension Program Note No. 04. URL: ***http://www.for.gov.bc.ca/hfd/Pubs/RSI/FSP/EN/RSI_EN04.htm***

Klenner, W. and D. Lewis. 2007. Retention planning for wildlife habitat and biodiversity during salvage harvesting, and some obstacles to implementation. *In* Overcoming Obstacles to Variable Retention in Forest Management: Science to Management Forum Proceedings, September 25–27, 2007. BC Journal of Ecosystems and Management 8(3):157–163. URL: ***http://www.forrex.org/publications/jem/ISS42/vol8_no3_scienceforum.pdf***

Klenner, W., R. Walton, and W. Kurz. 2000. Habitat for tomorrow: Understanding the consequences of today's decisions and natural disturbances on future habitat condition. *In* Proceedings of a conference on the biology and management of species and habitats at risk. Kamloops, B.C., February 15–19, 1999. L.M. Darling (editor). B.C. Ministry of Environment, Lands and Parks, Victoria, B.C. and University College of the Cariboo, Kamloops, B.C. Volume 1. URL: *http://www.env.gov.bc.ca/wld/documents/ft08klenner.pdf*

Lindenmayer, D.B. and J.F. Franklin. 2002. Conserving forest biodiversity: A comprehensive, multiscaled approach. Island Press, Washington, D.C.

Lindenmayer, D.B., D.R. Foster, J.F. Franklin, M.L. Hunter, R.F. Noss, F.A. Schmiegelow, and D. Perry. 2004. Enhanced salvage harvesting policies after natural disturbance. Science 303(5662):1303.

Lindenmayer, D.B., P.J. Burton, and J.F. Franklin. 2008. Salvage logging and its ecological consequences. Island Press, Washington D.C.

Martin, K., A. Norris, and M. Drever. 2006. Effects of bark beetle outbreaks on avian biodiversity in the British Columbia interior: Implications for critical habitat management. BC Journal of Ecosystems and Management 7(3):10–24. URL: *http://www.forrex.org/publications/jem/ISS38/vol7_no3_art2.pdf*

Paine, T.R., M.J. Tegner, and E.A. Johnson. 1998. Compounded perturbations yield ecological surprises. Ecosystems 1:535–545.

Payer, D.C. and D.J. Harrison. 2000. Structural differences between forests regenerating following spruce budworm defoliation and clearcut harvesting: implications for marten. Canadian Journal of Forest Research 30:1965–1972.

Perry, D.A. and M.P. Amaranthus. 1997. Disturbance, recovery, and stability. *In* Creating a forestry for the 21st century: The science of ecosystem management. K.A. Kohm and J.F. Franklin (editors). Island Press, Washington, D.C. pp. 31–56.

Shore, T.L. and L. Safranyik. 1992. Susceptibility and risk rating systems for the mountain pine beetle in lodgepole pine stands. Canadian Forest Service, Pacific Forestry Centre, Victoria, B.C. Information Report BC-X-336.

Snetsinger, J. 2005. Guidance on landscape- and stand-level structural retention in large-scale mountain pine beetle salvage operations. B.C. Ministry of Forests and Range, Victoria, B.C. URL: *http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/stewardship/cf_retention_guidance_dec2005.pdf*

Spies, T. 1997. Forest stand structure, composition and structure. *In* Creating a forestry for the 21st century: The science of ecosystem management. K.A. Kohm and J.F. Franklin (editors). Island Press, Washington, D.C. pp. 11–30.

Spittlehouse, D.L. 2008. Climate change, impacts, and adaptation strategies: Climate change and forest and range management scenarios in British Columbia. B.C. Ministry of Forests and Range, Research Branch, Victoria, B.C. Technical Report No. 045. URL: *http://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr045.htm*

Steeger, C. and C.L. Hitchcock. 1998. Influence of forest structure and diseases on nest-site selection by red-breasted nuthatches. Journal of Wildlife Management 62:1349–1358.

Steeger, C. and J. Dulisse. 1997. Ecological interrelationships of three-toed woodpeckers with bark beetles and pine trees. B.C. Ministry of Forests, Nelson, B.C. Extension Note No. 035. URL: *http://www.for.gov.bc.ca/rsi/research/nextnotes/Rs035.htm*

Steventon, D. 2006. Northern flying squirrel and red squirrels: Is there life after beetles and logging? Bulkley Valley Centre for Natural Resources Research and Management, Smithers, B.C. Extension Note No. 2. URL: *http://www.bvcentre.ca/pdf/Documents/Research/05-6SquirrelsBVRC-EN2Final.pdf*

Stone, W.E. 1995. The impact of a mountain pine beetle epidemic on wildlife habitat and communities in post-epidemic stands of a lodgepole pine forest in northern Utah. PhD thesis, Utah State University, Logan, Utah.

Sullivan, T.P. 2008. Stand structure and maintenance of biodiversity in green-tree retention stands at 30 years after harvest: A vision into the future "life after beetle." Final report to the Okanagan Innovative Forestry Society.

Sullivan, T.P. and D.S. Sullivan. 2001. Influence of variable retention harvests on forest ecosystems. II. Diversity and population dynamics of small mammals. Journal of Applied Ecology 38:1234–1252.

Sullivan, T.P., D.S. Sullivan, and P.M.F. Lindgren. 2000. Small mammals and stand structure in young pine, seed tree, and old-growth forest, southwest Canada. Ecological Applications 10(5):1367–1383.

Taylor, S.W. and A.L. Carroll. 2004. Disturbance, forest age, and mountain pine beetle outbreak dynamics in British Columbia: A historical perspective. *In* Mountain pine beetle symposium: Challenges and solutions, October 30–31, 2003, Kelowna B.C. T.L. Shore, J.E. Brooks, and J.E. Stone (editors). Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, B.C. Information Report BC-X-399. pp. 41–51.

Thompson, I.D. and A.S. Harestad. 1994. Effects of logging on American marten and models for habitat management. *In* Martens, sables and fishers: Biology and conservation. S.W. Buskirk, A.S. Harestad, M.G. Raphael, and R.A. Powell (editors). Comstock Publishing Associates, Ithaca, N.Y. pp. 355–367.

Vyse, A., C. Ferguson, D. Huggard, J. Roach, and B. Zimonick. 2007. Regeneration beneath pine stands in the Kamloops TSA. Thompson Rivers University, Kamloops, B.C.

Wilson, S.J. and R.J. Hebda. 2008. Mitigating and adapting to climate change through the conservation of nature. The Land Trust Alliance of British Columbia, Salt Spring Island, B.C.

Wong, C., B. Dorner, and H. Sandmann. 2003. Estimating historical variability of natural disturbances in British Columbia. B.C. Ministry of Forests, Research Branch, and B.C. Ministry of Sustainable Resource Management, Resource Planning Branch, Victoria, B.C. Land Management Handbook No. 53. URL: ***http://www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh53.pdf***

Wood, C.S. and L.S. Unger. 1996. Mountain pine beetle: A history of outbreaks in pine forests in British Columbia, 1910 to 1995. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, B.C. URL: ***http://www.for.gov.bc.ca/hfd/library/documents/bib41679.pdf***

Mountain pine beetle and watershed hydrology

Todd Redding[1], Rita Winkler[2], Pat Teti[3], Dave Spittlehouse[4], Sarah Boon[5], John Rex[6], Stephane Dubé[7], R.D. Moore[8], Adam Wei[9], Martin Carver[10], Markus Schnorbus[11], Lars Reese-Hansen[12], and Steve Chatwin[13]

Abstract

Changes to British Columbia's lodgepole pine forests due to the mountain pine beetle (MPB) outbreak will affect stand water balances, hillslope hydrology, and streamflow in many watersheds. The magnitude of this disturbance has prompted a range of research at both stand and watershed scales to address uncertainty about the hydrologic effects of MPB, such as an increased potential for flooding; changes in water yield, peak flows, and low flows; slope and channel changes associated with increased runoff, as well as the effects of hydrologic change on aquatic habitat and drinking water. This paper summarizes the key hydrologic changes expected. It also highlights the results of research currently under way throughout the British Columbia Interior and other regions to quantify changes in hydrologic processes and potential effects at the stand and watershed scales of MPB-related stand mortality and salvage harvesting. General forest planning recommendations and sources of further information are provided.

KEYWORDS: *hydrology, mountain pine beetle, salvage harvesting, streamflow, watershed management.*

Contact Information

1 Watershed Management Extension Specialist, FORREX, 527 Duke Street, Nanaimo, BC V9R 1K2. Email: todd.redding@forrex.org

2 Research Hydrologist, B.C. Ministry of Forests and Range. Email: Rita.Winkler@gov.bc.ca

3 Research Hydrologist, B.C. Ministry of Forests and Range. Email: Pat.Teti@gov.bc.ca

4 Research Climatologist, B.C. Ministry of Forests and Range. Email: Dave.Spittlehouse@gov.bc.ca

5 Assistant Professor, Department of Geography, University of Lethbridge. Email: sarah.boon@uleth.ca

6 Research Hydrologist, B.C. Ministry of Forests and Range. Email: John.Rex@gov.bc.ca

7 Research Soil Scientist, B.C. Ministry of Forests and Range. Email: Stephane.Dube@gov.bc.ca

8 Forest Renewal BC Chair of Forest Hydrology, Department of Geography, University of British Columbia. Email: rdmoore@geog.ubc.ca

9 Associate Professor, Department of Earth and Environmental Sciences, UBC Okanagan. Email: adam.wei@ubc.ca

10 A/Director, Water Group, Health Protection, B.C. Ministry of Healthy Living and Sport. Email: Martin.Carver@gov.bc.ca

11 Hydrologic Modelling Scientist, B.C. Ministry of Environment. Email: Markus.Schnorbus@gov.bc.ca

12 Fisheries Sensitive Watershed Biologist, B.C. Ministry of Environment. Email: Lars.ReeseHansen@gov.bc.ca

13 Special Projects Manager, Forest Practices Board. Email: Steve.Chatwin@gov.bc.ca

***JEM* — VOLUME 9, NUMBER 3** *Published by FORREX Forum for Research and Extension in Natural Resources*

Redding, T., R. Winkler, P. Teti, D. Spittlehouse, S. Boon, J. Rex, S. Dubé, R.D. Moore, A. Wei, M. Carver, M. Schnorbus, L. Reese-Hansen, and S. Chatwin. 2008. Mountain pine beetle and watershed hydrology. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):33–50. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Introduction[1]

The forested watersheds of British Columbia's Interior are a primary water source for aquatic ecosystems and human populations. The current mountain pine beetle (MPB) infestation and associated salvage harvesting have the potential to affect the amount, timing, and quality of water originating from these watersheds. This paper provides a review of research on the effects of the MPB and salvage harvesting on watershed hydrology, and how these activities may affect watershed function.

The current mountain pine beetle infestation and associated salvage harvesting have the potential to affect the amount, timing, and quality of water originating from British Columbia's forested watersheds.

The hydrologic changes resulting from MPB mortality and harvesting are primarily related to the loss of canopy cover. When the forest canopy is reduced through MPB-induced mortality or removed through salvage harvesting, hydrological processes such as interception and transpiration are affected (Figure 1). In general, this results in more water reaching the ground surface and potentially more water available for streamflow. Increased streamflows may have positive (e.g., more water available for human or ecological needs) or negative (e.g., increased flood potential, degraded water quality) effects. Therefore, understanding the magnitude and direction of changes is critical to account for hydrological risks in management and planning for both the forested watersheds and the valley-bottom infrastructure and water-users. Watershed-specific impacts may also be difficult to accurately predict

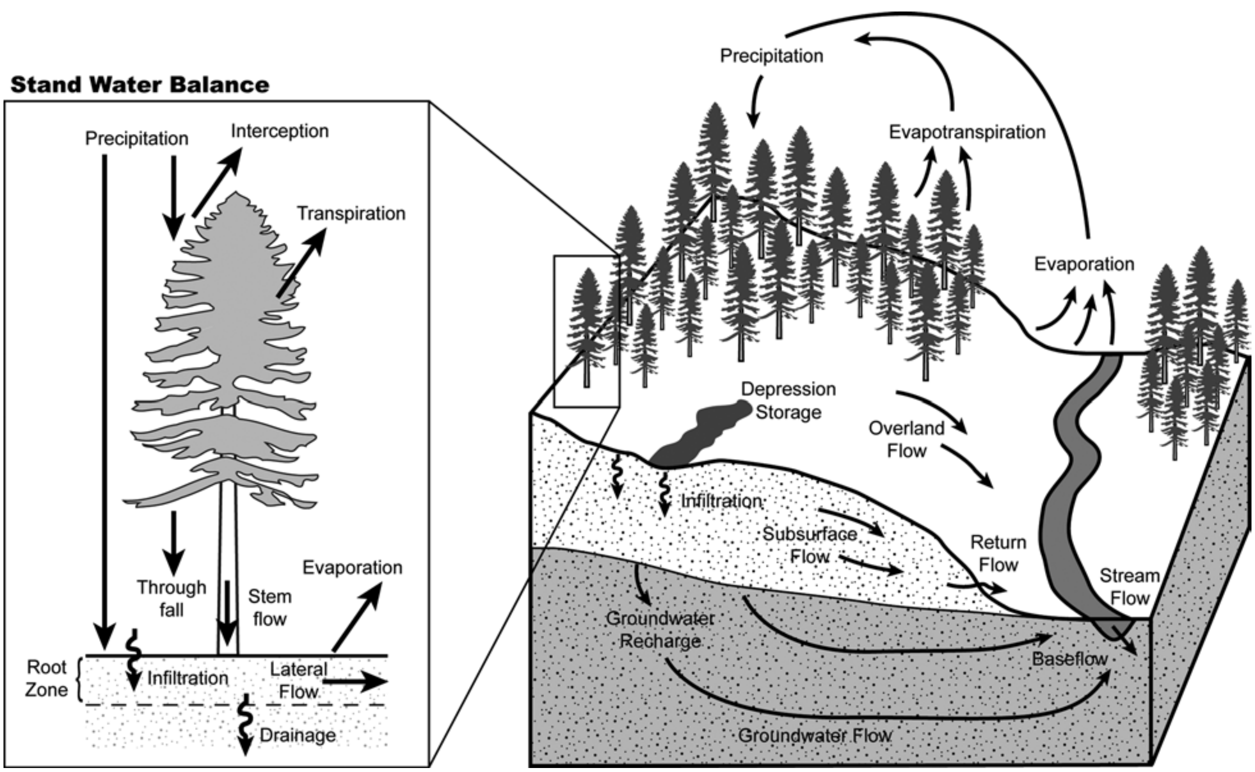

FIGURE 1. Hillslope hydrologic cycle and stand water balance. The loss of forest canopy influences the interception of precipitation and the subsequent loss through evaporation and transpiration (adapted from Winkler *et al.*, forthcoming).

[1] Portions of this document have been reproduced from (with permission): Winkler, R.D., J. Rex, P. Teti, D. Maloney, and T. Redding. 2008. Mountain pine beetle, forest practices, and watershed management. B.C. Ministry of Forests and Range, Research Branch, Victoria, B.C. Extension Note No. 88. URL: *http://www.for.gov.bc.ca/hfd/pubs/Docs/En/En88.pdf*

because of the variable influences of geology, topography, soils, and vegetation on hydrological response.

This paper summarizes the expected changes in water cycling as a result of the MPB infestation and associated salvage harvesting. It is based, in part, on presentations at the Mountain Pine Beetle: From Lessons Learned to Community-based Solutions conference held in Prince George, B.C., June 10–11, 2008. In addition, portions of the paper have been reproduced (with permission) from Winkler *et al.* (2008). Other recent publications on this subject include Uunila *et al.* (2006), Hélie *et al.* (2005), and Environmental Dynamics Inc. (2008). Specifics on other critical areas of consideration when dealing with MPB-affected stands, such as stand dynamics, biodiversity, and forest fire fuel management were outlined by other conference presenters (see, for example, synthesis papers by Swift [page 17], Lewis [page 24], and Hawkes [page 77]).

Effects of Mountain Pine Beetle and Salvage Harvesting on Hydrological Processes and Watershed Response

The effects of forest disturbance (including MPB and salvage harvesting) are typically investigated at the stand and watershed scales. The stand-scale effects investigated include snow accumulation and melt, rainfall interception, stand water balance, stand and hillslope subsurface hydrology, and hydrologic recovery. Watershed-scale effects include effects on streamflow, aquatic ecology, and water quality.

Redding *et al.* (2007b) developed a generalized illustration of the relative changes in hydrologic processes and watershed response to loss of canopy (e.g., through MPB mortality, salvage harvesting, fire, etc.) that shows how hydrologic variables change along a gradient of canopy cover (Figure 2). Although this is a useful tool for understanding the interaction of different processes, it is not meant to provide absolute magnitudes of response or address unique site conditions.

Stand-scale Effects

Snow Accumulation and Melt

A significant portion of total winter precipitation is intercepted by forest canopies and lost through sublimation. The forest canopy not only reduces snow accumulation relative to open areas, it also influences how quickly snow disappears. Snow surveys throughout the Interior show large annual, geographic, and forest-cover-related variability in snow accumulation and ablation, even over distances of only a few kilometres (Winkler *et al.* 2004; Winkler 2007). Storm type also significantly influences canopy interception. This was

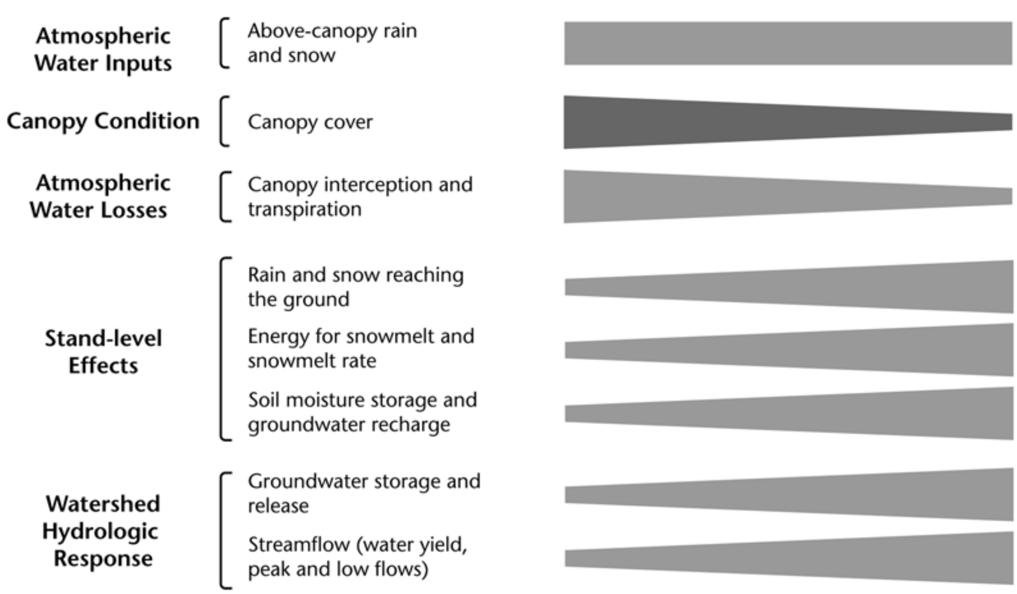

FIGURE 2. The influence of forest canopy alterations on water cycling. The thickness of a wedge represents the trend in a process or effect as the canopy cover (black wedge) is altered; it does not indicate the magnitude of the process or effect. Where the canopy cover is highest (wedge thickest), it is representative of a well-stocked healthy mature stand. Where it is lowest (wedge thinnest), it is indicative of a recent clearcut (adapted from Redding *et al.* 2007b).

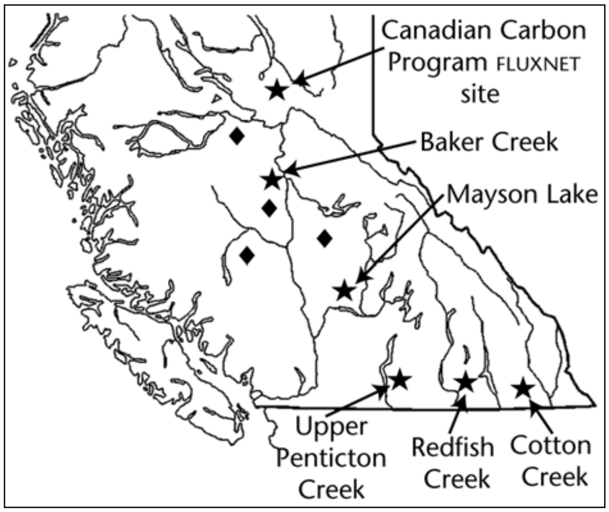

FIGURE 3. Ongoing stand-level research projects examining disturbance effects on hydrological processes. Sites denoted by diamonds are those limited to studies of snow accumulation and melt; at those sites denoted by stars, research covers a range of hydrological processes (including snow accumulation and melt).

evident particularly in dead stands with a coniferous understorey where, during major winter storms, young trees (< 1.3 m tall) were snow-pressed, which limited interception by these canopies (Boon 2007b).

Changes in snow accumulation attributed to changes in canopy cover have been studied at many sites in British Columbia (Figure 3). At long-term research sites on the Thompson-Okanagan Plateau, the maximum snow water equivalent (SWE; liquid water held in the snowpack) in mature lodgepole pine stands averages 11% less than that in recent clearcuts (Winkler 2007). These reductions are smaller than those observed in mixed-species stands at these study sites. Up to 44% less SWE at maximum accumulation has been measured in the mixed-species stands relative to nearby clearcuts. Recently initiated surveys in MPB-attacked stands near Vanderhoof have shown that, at maximum accumulation, SWE in a stand that had lost its needles (grey-attack stage) and in a green mixed-species stand was 53% and 73% less, respectively, than that measured in a clearcut (Boon 2007a). In another study also located in the Central Interior, snow surveys in mixed-species green forest stands near Prince George showed that maximum SWE was 50–60% less than that in nearby clearcuts and that SWE in a grey stand was roughly halfway between; however, little difference was observed in snow accumulation between a green pine stand and a grey pine stand near Prince George during a year of low snowfall (Beaudry 2007).

Snow ablation rates (the loss of snow through both melt and vaporization) are, on average, 15% lower, and snow persists for up to 8 days longer in the forest than in the open (Winkler 2007). In addition, up to 60% slower ablation rates were measured in the mixed-species stands relative to nearby clearcuts (R. Winkler, pers. comm., 2008). Snow ablation rates are decreased by forest canopies partly because of the reduced solar radiation at the snow surface relative to that in the open (Spittlehouse and Winkler 2004). Current research in British Columbia (Teti and Winkler 2008; D. Spittlehouse, pers. comm., 2008) shows that old pine stands which have not been defoliated, and mixed-species, pine-leading stands, transmit 15–30% of solar radiation in early spring depending on the canopy and stand density. This level increases as the stand deteriorates over many years. In a stand attacked in the 1980s, where previous canopy-forming trees had fallen and natural regeneration was well established, transmittance to the snowpack was 57% (P. Teti, pers. comm., 2008). In contrast, salvage harvesting increased radiation transmittance to virtually 100% for at least 10 years (Teti and Winkler 2008). Transmission of radiation to the snowpack decreased rapidly after this time, dropping to approximately 20% within 35 years of logging.

Snow accumulation and ablation recovery (defined as the decrease towards that in the mature forest) were 43% and 29%, respectively, in 20-year-old pine stands. Thinning to remove approximately one-half of the stems did not affect maximum snow accumulation, but reduced snow ablation recovery to 13% (Winkler *et al.* 2005). On the Fraser Plateau, Teti (2007) found that snow ablation rates in young stands are very similar to those in a clearcut for at least 12 years. However, in 35-year-old forests, ablation rates are very similar to those in mature forest. Data from all snow surveys in the Thompson-Okanagan show a 6% reduction in April 1 SWE with every 10% increase in crown closure to a maximum of 55% reduction in SWE (Winkler and Roach 2005).

In large openings at several steeply sloping south-facing study sites in the Okanagan, higher SWE is measured in the forest than in the open at the time of maximum accumulation, indicating that periodic snow disappearance occurs in the open before the main melt season (R. Winkler, pers. comm., 2008). These losses occur due to wind scour, sublimation, and possibly melt during warm periods in mid-winter, and potentially mitigate the effects of increased SWE at other sites across the landscape, resulting in desynchronization of snowmelt and streamflow generation.

Rainfall Interception

Limited research has been conducted on changes in rainfall interception that result from canopy deterioration following MPB attack. In mature mixed pine, spruce, and subalpine fir forests, the canopy intercepts and subsequently evaporates approximately 30% of growing-season precipitation, reducing the amount of water reaching the ground (Spittlehouse 2007). At Mayson Lake north of Kamloops and Penticton Creek in the Okanagan, measurements of rainfall interception indicate approximately 40% of growing-season rainfall is lost in a mature stand (Redding *et al.* 2007c; Winkler *et al.* forthcoming). A well-developed understorey below an old MPB-killed stand intercepted as much rain as live trees (Schmid *et al.* 1991). Storage and subsequent evaporation of rainfall in the litter and moss layers on the forest floor accounts for 20–30% of growing-season precipitation in low rainfall regimes (Carlyle-Moses 2007). In mature lodgepole pine stands in the Rocky Mountain foothills of Alberta, Silins *et al.* (2007) estimated that on average 44% of growing-season precipitation is lost to canopy and forest floor interception in mature stands.

Stand Water Balance

Atmospheric water losses (interception, transpiration, and soil evaporation) in mature pine stands in British Columbia (Spittlehouse 2007) and Alberta (Silins *et al.* 2007) typically account for 60–70% of annual precipitation inputs, with 30–40% of precipitation draining below the rooting zone and available for groundwater recharge and (or) to generate streamflow. Following MPB infestation and salvage harvesting, the proportions of water balance components in an individual stand will change, resulting in an increase in drainage. Water balance modelling carried out for study stands at the Upper Penticton Creek Watershed Experiment indicates that after MPB attack and salvage harvesting more water would be available to recharge groundwater and generate streamflow (Figure 4; Spittlehouse 2007). When compared with mature lodgepole pine forest, red-attack stands show similar amounts of interception loss, while the grey-attack and clearcut stands show reduced interception. Plant transpiration plus soil evaporation are similar between the mature and clearcut stands, and reduced in the red- and grey-attack stands. The most water available for groundwater recharge and streamflow is in the clearcut and grey-attack stands with the red-attack stands intermediate and the mature stand lowest. The modelling indicates that a stand with less than 40% of the trees attacked has a similar hydrological balance to the attacked stand.

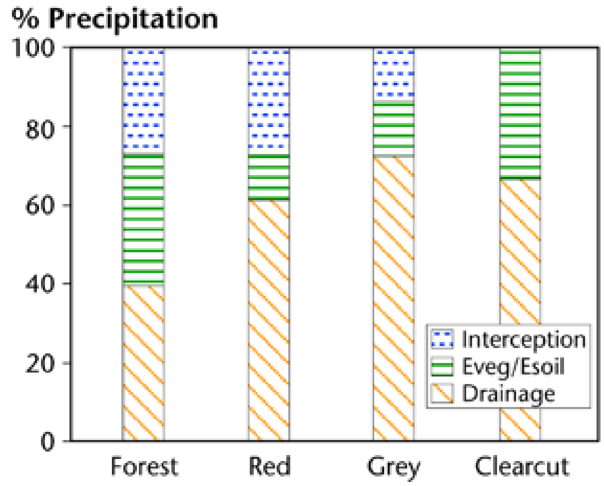

FIGURE 4. Modelled mean annual stand water balance for mature, red, grey, and clearcut lodgepole pine stands at Upper Penticton Creek. Data are results of a process-based stand water balance model run at a daily time step from October 2002 to September 2006. Meteorological inputs (precipitation, temperature, humidity, and above-canopy radiation) and soil properties were held constant for all stands, and only canopy properties were varied (adapted from Spittlehouse 2007). "Interception" represents the amount of precipitation intercepted by the canopy and subsequently evaporated; "Eveg" and "Esoil" represent plant transpiration and evaporation from the soil surface, respectively; "Drainage" represents water that moves vertically below the rooting zone and is potentially available for groundwater recharge and streamflow.

Subsurface Hydrology

With changes in the stand water balance resulting in greater drainage, and hence water available for groundwater recharge, reports of rising water tables affecting trafficability and forest harvesting operations in some areas of heavy infestation and salvage harvesting are not surprising (Rex and Dubé 2006; Dubé and Rex 2008). In the Vanderhoof Forest District in central British Columbia, Rex and Dubé (2006) noted elevated water-table levels in lowland areas (e.g., toe slopes, wetlands, or lowland landscapes) after harvesting. The risk of wet ground increased with:

- decreasing drainage density;
- decreasing understorey vegetation;
- increasing area of sensitive soils (poorly drained or fine texture); and
- increasing pine cover (Dubé and Rex 2008).

Decreased efficiency of surface water drainage and rising water tables can affect the selection of appropriate silvicultural systems (Pothier *et al.* 2003), post-harvest species selection (Landhausser *et al.* 2003), and trafficability (Rex and Dubé 2006).

Little available literature examines changes in hillslope runoff generation before and after harvesting; however, two studies are available with relevance to conditions in British Columbia. In Idaho, Megahan (1983) measured a large post-disturbance (harvest and wildfire) increase in both subsurface stormflow volume (+ 96%) and flow rate (+ 27%) during the snowmelt period. The increase in volume and rate was attributed to a post-disturbance increase in both SWE and melt rates for the study hillslopes. At the Fraser Experimental Forest in Colorado, Troendle and Ruess (1997) measured an increase in annual hillslope outflows from 15% of incoming precipitation under forested conditions to 60% of incoming precipitation for clearcut conditions. The changes were attributed to greater snow accumulation and reduced transpiration for the clearcut plot.

Hydrologic Recovery

For a given set of weather conditions, the magnitude and duration of stand-scale hydrologic change associated with MPB will depend on:

- the percentage of overstorey that has been killed;
- the presence, age, and density of advance regeneration and understorey vegetation; and
- the stand's logging history.

If MPB-attacked stands are left to deteriorate naturally, hydrologic change will be more gradual as trees turn from green to red, drop their needles, turn grey, lose fine branches, and eventually fall to the ground (Huggard and Lewis 2007). At the same time, understorey vegetation may release due to increased light and reduced competition for nutrients and water. In contrast, clearcut salvage harvesting causes a large immediate change to the site water balance through removal of the overstorey. The hydrologic change associated with salvage harvesting will also vary with the amount of ground disturbance, intensity and type of site preparation, degree of drainage disruption, degree of understorey damage, and rate of forest regrowth.

To address uncertainties around MPB impacts on stand-level hydrological recovery, Huggard and Lewis (2007) used models of stand tree growth, field data on understorey composition, and measurements of hydrologic recovery as snow accumulation and melt to generate recovery curves for various forest management options in select Interior Douglas-fir and Montane Spruce biogeoclimatic subzones in the southern interior of British Columbia. The results indicate that clearcut salvage harvesting and planting results in the greatest increase in equivalent clearcut area (ECA) and quickest recovery (see Figure 5 for hypothetical example). Full retention of the dead stand shows the lowest maximum ECA, but the most prolonged full recovery (Figure 5). In selecting a retention or salvage strategy, it will be necessary to balance the risk of a more intensive disturbance with the benefit of a quicker recovery (Huggard and Lewis 2007).

Watershed-scale Effects

Watershed-scale effects of forest disturbance can be difficult to quantify because of large natural variability in climate, geology, and other factors that control streamflow generation and timing. Two main

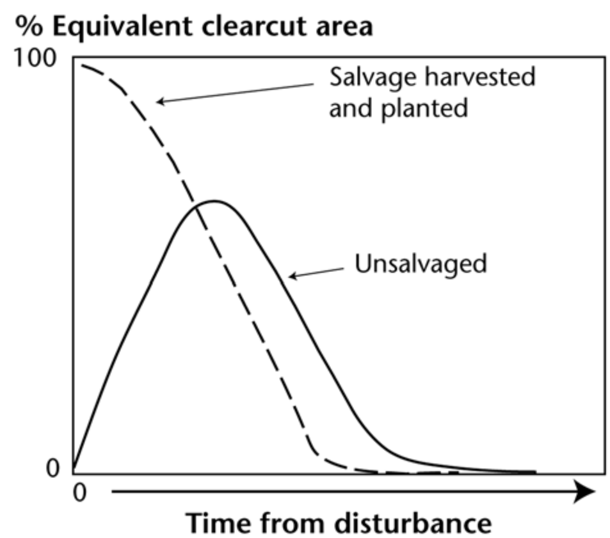

FIGURE 5. Hypothetical hydrological recovery trajectories for salvaged and planted and unsalvaged stands (complete retention). A lower value of equivalent clearcut area indicates greater hydrological recovery (adapted from Huggard and Lewis 2007).

approaches have been used to examine the effects of MPB and salvage harvesting on streamflow: retrospective streamflow analyses and numerical modelling. For retrospective streamflow analyses, long-term streamflow records are analyzed to quantify disturbance effects. The second method is the application of hydrologic simulation models to examine the impacts of various infestation and salvage-harvesting scenarios on streamflow. For further information on the different approaches, see Pike *et al.* (2007).

Retrospective Streamflow Analyses

At Camp Creek in the Okanagan basin, 30% of the watershed was salvage-harvested in 1976–1977 following MPB infestation (Cheng 1989). A paired-watershed analysis showed that annual water yields increased by 21%, peak flows increased by 21%, peak flow timing advanced by 13 days, and April flows also increased (Cheng 1989; Moore and Scott 2005). The duration of peak flow increase lasted approximately 15 years, while elevated April flows persisted for the length of data record. These values generally agree with stand-level measurements of hydrologic recovery of snow accumulation and melt processes (Moore and Scott 2006). No changes in low flows were detected (Moore and Scott 2005).

Extensive forest harvesting has taken place in both the Bowron River and adjacent Willow River watersheds in central British Columbia. Large-scale harvesting occurred in the Bowron River watershed in response to a spruce beetle outbreak in the 1970s. Both watersheds are large (Bowron: 3590 km^2; Willow 3110 km^2) and have long-term streamflow records (Wei and Lin 2007; Lin and Wei 2008). Statistical time series analyses were applied to the data to detect effects related to forest harvesting. No statistically significant effects of salvage harvesting were detected on annual water yields, peak flows, or low flows for the Bowron River watershed (Wei and Lin 2007). In the adjacent Willow River watershed, Lin and Wei (2008) found significant increases in spring and annual peak flows, and an increase in annual water yield that was attributable to harvesting. Neither watershed showed any significant changes in low flows. The reasons given for variable effects of harvesting on these adjacent watersheds included differences in watershed characteristics, climate, and the timing and location of harvesting (Wei and Lin 2007).

The Fishtrap Creek watershed, near Kamloops, B.C., was severely affected by wildfire during the summer of 2003. Since then, an increase in flows occurs during the early stage of the freshet, and high flow periods are lasting longer than before the fire. The earlier and longer period of high flows may be the result of changes in snowmelt dynamics in the basin resulting in a desynchronization of basin melt (Moore *et al.* 2008). The longer duration of high flows appears to be affecting channel processes and sediment movement through the burnt floodplain of the watershed (Moore *et al.* 2008).

Similar increases in peak flow and water yield were found in Montana and Colorado. In Montana, a watershed with 35% defoliation had a 15% increase in annual water yield (Potts 1984). Although no changes were evident in peak flow magnitude, the annual peak occurred 14–21 days earlier and high flow conditions persisted longer with a greater spring monthly water yield. In addition, low flows increased by 10%. In two Colorado watersheds following defoliation of 30% of their area, annual water yield increased 16%. Peak flows occurred 2–11 days earlier and were 4–27% larger following defoliation; low flows also increased 10–31% (Bethlahmy 1975).

Hydrologic Simulation Modelling of Mountain Pine Beetle Infestation and Salvage-harvesting Scenarios

To examine the potential effects of extensive MPB infestation and salvage harvesting on peak flows and water yield, the Distributed Soil-Vegetation-Hydrology Model (DHSVM) was applied to the 1570 km^2 Baker Creek Watershed near Quesnel, B.C. (Forest Practices Board 2007). The model was run with four scenarios:

1. baseline with 13% watershed area harvested and 0% watershed area MPB affected;
2. conventional harvesting with 28% area harvested and a further 2% area MPB affected;
3. MPB epidemic with 34% area harvested and a further 53% area MPB affected; and
4. salvage harvest with 80% watershed area harvested and a further 17% area MPB affected.

The results of scenarios 3 and 4, with the largest amounts of harvesting and MPB-affected area, were striking. For scenario 3, the model predicted a 60% increase in mean annual peak flow and an advance in peak flow timing of 15 days (Forest Practices Board 2007). For scenario 4 with the maximum amount of salvage harvesting, peak flows were predicted to increase by 90% and occur 16 days earlier (Forest Practices Board 2007). The results indicated the potential for a major shift in flood frequency in the watershed; floods with a baseline return period of 20 years may increase to a return period of 3 years under scenario 4. This shift would have major implications for the design of infrastructure on the floodplain and highlights the need to plan the extent of clearcut salvage harvesting in infested watersheds, designate reserve areas, and carefully design stream crossings (Forest Practice Board 2007).

To examine the effects of MPB and salvage harvesting on streamflows, two hydrologic models were applied in the Okanagan basin. The HBV-EC model, which has relatively modest data requirements, was able to reproduce the statistical distributions of post-harvesting streamflow changes (Moore *et al.* 2007). Streamflows in any given year were not always accurately simulated, likely due to an overly simplistic model representation of canopy influences on snow accumulation processes (Moore *et al.* 2007). The University of British Columbia Watershed Model was applied to simulate the effects of complete clearcut harvesting on peak flows and water yield for a number of Okanagan tributary watersheds (Alila and Luo 2007). The results show peak flow increases of 30–100% for 1- and 2-year return period events and freshet water yield increases of 40–75%.

Modelling of streamflow response to MPB and salvage-harvesting scenarios for pine-dominated watersheds of the Alberta Rocky Mountain foothills also predicts the potential for dramatic changes in streamflow (Rothwell and Swanson 2007). The WRENSS model was applied to four watersheds between Grand Prairie and Grand Cache using a scenario of reducing pine cover by 75% within 20 years. Annual water yields were predicted to increase by 9–29%; 2-year return period flows were predicted to increase by 7–53%, and 100-year return period flows to increase by 1–20% (Rothwell and Swanson 2007). The predicted average time to reach pre-MPB conditions was 44 years.

Impacts on Aquatic Ecology

Changes in streamflow regimes following watershed disturbance have the potential to affect aquatic communities and processes (Johannes *et al.* 2007). Large woody debris (LWD) in streams is critical for habitat formation; harvesting in riparian zones can potentially disrupt these inputs. Source-distancing research completed under the Prince George Small Streams Study identified that the majority of active in-stream LWD originated within 10 m of the streambank (Beaudry and Beaudry, forthcoming). In the Okanagan, Wei *et al.* (2007) found similar LWD input rates between MPB-attacked and non-attacked stands; however, the MPB-attacked stands show greater LWD movement distances. In the Bowron River watershed, riparian harvesting in the 1970s continues to affect LWD recruitment and stream recovery (Nordin 2008). In pine-leading stands of the Central Interior, spruce can be the dominant species in riparian zones, indicating that riparian retention is a viable option to maintain aquatic values (Rex 2007). Protecting riparian function and aquatic habitat will have major implications for fish populations, including salmon throughout the Interior of British Columbia (Johannes *et al.* 2007).

Impacts on Water Quality

Little research has been undertaken on the effects of the MPB infestation on water quality; however, based on knowledge from other forest disturbances, some generalizations are possible. Increased road building and stream crossings for salvage harvesting may potentially increase sediment delivery to watercourses. Given the potential for increased flows discussed earlier, it may be necessary to design structures to a higher standard. At Fishtrap Creek in southern British Columbia, mortality of the riparian canopy due to wildfire resulted in a loss of bank strength that caused significant channel change and associated transient increases in suspended sediment concentration (Moore *et al.* 2008). Chemical properties of surface waters may be affected by the MPB infestation and salvage harvesting due to associated changes in water fluxes and biogeochemical cycling. In Colorado, elevated stream water nitrate concentrations were evident after MPB infestation of watersheds and have persisted for a number of years, but remain below drinking water standards (Stednick 2007).

The loss of riparian cover due to canopy mortality or harvesting can lead to increases in stream temperature, which may adversely affect aquatic processes and fish productivity (Moore *et al.* 2005). Although no studies have specifically examined the effects of MPB-related canopy loss on stream temperature, studies that examine harvesting effects in the Central Interior can provide some guidance. For instance, Mellina (2006) found that headwater streams in this area typically feature downstream warming trends, and lake-headed streams feature downstream cooling. The effects of riparian harvesting on stream temperature were greatest for headwater streams compared to lake-headed streams; these disparities may be partially related to differences in groundwater inflows (Mellina 2006). A model is available that can help predict the potential effects of harvesting on stream temperatures (Mellina *et al.* 2002; Mellina 2006). At Fishtrap Creek, the burnt canopy reduced the net radiation reaching the stream surface by about 30% compared to no standing dead vegetation; radiation under the standing dead trees was 50% greater than for pre-fire conditions (Moore *et al.* 2008).

Management Tools

Various tools have been developed, or are currently under development, to assist managers and planners in assessing the potential impacts of the MPB infestation and salvage harvesting on watershed values.

Planning and Operational Tools

Forest and Range Evaluation Program: Fish/Riparian Evaluation Procedure

The goal of monitoring the condition of stream channels and their adjacent riparian management areas is to determine whether *Forest and Range Practices Act* standards and practices governed by regulation are achieving the desired result of protecting fish values by maintaining channel and riparian functions. The specific Forest and Range Evaluation Program (FREP) monitoring question is: "Are riparian forestry and range practices effective in maintaining the structural integrity and functions of stream ecosystems and other aquatic resource features over both short and long terms?" (Tripp *et al.* 2008). Given the linkages between aquatic ecosystems and fish habitats within watersheds, interpretations of effectiveness are relevant not only for site-specific management, but also to determine downstream or downslope effects, and cumulative watershed effects. The main questions addressed by the FREP Fish/ Riparian Evaluation Procedure are:

- Are riparian forestry and range practices effective in maintaining the structural integrity and functions of stream ecosystems and other aquatic resource features over both short and long terms?
- Are forest road stream crossings or other forestry practices maintaining connectivity of fish habitats?
- Are forestry practices, including those for road systems, preserving aquatic habitats by maintaining hillslope sediment supply and the sediment regimes of streams and other aquatic ecosystems?

For more information, please visit: ***http://www.for.gov.bc.ca/hfp/frep/values/fish.htm***

FREP: Water Quality Effectiveness Evaluation Procedure

Watershed managers want to determine the effects of forestry and range uses on water quality. When negative impacts caused by fine sediment generation or fecal contamination are confirmed, they need to prioritize actions that will economically mitigate the impacts. The Water Quality Effectiveness Evaluation procedure is a tool that:

- identifies common disturbed forestry and livestock sites that may generate fine sediment (slope failures, road stream crossings, road paralleling streams, windblown riparian leave strips, etc.) and fecal contamination; and
- determines if and how much such sites affect water quality, and provides clear management options to reduce sediment generation at the particular site.

For more information, please visit ***http://www.for.gov.bc.ca/hfp/frep/values/water.htm***

Identifying the Risk of Wet Ground

To address concerns about the limiting effects of rising water tables on forest operations in certain watersheds of the Vanderhoof Forest District, Ministry of Forests and Range researchers developed and tested a tool to identify the risk of wet ground (Dubé and Rex 2008). The method ranks watersheds based on their potential for elevated water tables or drainage problems. The hydrologic risk indicators for potential wet ground are those factors that control the delivery of precipitation to the ground surface (e.g., infestation characteristics) and those that affect the retention of water in the watershed (e.g., watershed characteristics). All of the risk indicators can be quantified on the basis of information available from provincial spatial data resources. The combination of indicators that effectively predict the risk of wet ground are: drainage density, understorey cover, proportion of area with sensitive soils, and proportion of pine cover (Dubé and Rex 2008). The method has been shown to work well for the Vanderhoof Forest District. Some field verification would be required to apply the tool in other areas. For more information, please contact Stephane Dubé (***Stephane.Dube@gov.bc.ca***) or John Rex (***John.Rex@gov.bc.ca***).

B.C. Ministry of Environment: Fisheries Sensitive Watersheds and the Watershed Evaluation Tool

British Columbia's fisheries resources, including the watersheds on which they rely, are an important social, economic, and ecological feature of the province's landscape. Historically, various fisheries management initiatives have been aimed at evaluating watershed sensitivity and protecting fish values. Typically, these were targeted at site-specific stocks or locations, and identified areas in an ad hoc fashion with little consideration for assessing higher fish values at the watershed scale and over the broader landscape. Recognizing the weaknesses of this method, under the *Forest and Range Practices Act*, and using the Government Actions Regulation to legally designate "fisheries sensitive watersheds" (FSW), government has developed a prototype model called the Watershed Evaluation Tool (WET) to comparatively assess watersheds across the larger landscape. A GIS-based (vector) tool, WET has been designed to evaluate and numerically rank third-order (or larger) watersheds at the 1:50 000 scale. Using a consistent methodology, the tool can be applied to various predefined geographic areas ranging in size from the entire province down to a sub-regional scale. The model uses an assortment of consistently available indicators to evaluate each watershed's inherent physical sensitivity and fish values. These indicators are derived from numerous sources including: interpolations of TRIM data, watershed statistics, baseline thematic mapping, modelling, and inventories. The indicators are combined in a series of systematic, normalized, and linear process steps to determine a single relative score or rank for each watershed within a predetermined geographic population of watersheds. Although the tool was designed to help legally designate FSWs, it has other important applications including prioritizing watersheds for restoration, compliance monitoring, and assessing fisheries impacts in watersheds affected by MPB. It was also successfully used to prioritize watersheds for fish passage (culvert) assessment and improvements. For more information, contact Lars Reese-Hansen, B.C. Ministry of Environment (***Lars.ReeseHansen@gov.bc.ca***)

B.C. Ministry of Environment: Risk-based Models

The B.C. Ministry of Environment (Water Stewardship Division) has been developing an office-based assessment framework as a standardized system for hydrologic hazard assessments. The models under development focus on the physical processes important to the assessed hazards and risks. Data is used at a scale appropriate to each process, making the models relevant for a range of applications at the strategic and local planning levels. The assessment process is applied in a GIS environment, with widely available data sets. Basic inputs for the assessment include characterization of the watershed assessment units, identification of threats, and modelling of potential changes to the hydrologic system resulting from interactions within an assessment unit of a watershed's characteristics and associated threat activities. Inherent risks, past impacts, and potential future impacts are all considered separately. One of the component models (peak flow) is introduced below ("Hydrologic Modelling Initiatives"). Hydrologic hazards will be used to help identify values at risk and potential consequences that may result for each value. For further information, contact Martin Carver, B.C. Ministry of Healthy Living and Sport (***Martin.Carver@gov.bc.ca***).

Hydrologic Modelling Initiatives

Predicting the impact of a range of disturbance types on watershed hydrology and then determining the cumulative hydrologic effects is a complicated process. Given the costs and difficulties of conducting watershed-scale field research, hydrologic models will become more widely used to predict the effects of disturbance and climate change on forested watersheds and to test alternative forest management scenarios for their impacts on water resources.

- FORREX is partnering with Alberta Sustainable Resource Development and the B.C. Ministry of Forests and Range to develop a comprehensive synthesis of hydrological models for forest management applications. Forest managers need a method to identify the most appropriate models to answer specific management-related questions under a range of conditions. The project's objective is to describe hydrologic models in terms of their data requirements, assumptions, limitations, and outputs and thereby define their applicability to the forest land base of British Columbia and Alberta. This synthesis will provide a decision-support tool to identify appropriate hydrologic models for a range of circumstances (e.g., landscape characteristics, required outputs, management questions, spatial scale, data availability, etc.). This will ensure that the model outputs (i.e., the information on which management decisions are based) are credible and reliable. The model synthesis results will be published in spring 2009 as a FORREX Series report and a summary article in the Streamline Watershed Management Bulletin.
- The B.C. Ministry of Environment is leading a project to apply a large-scale hydrologic model (VIC model) to investigate the impacts of the MPB

infestation and salvage harvesting on flows in the Fraser River Watershed (Schnorbus 2008). Model calibration and validation are ongoing and results are expected by March 2009. The results of this study will provide guidance around the possible impacts of the MPB disturbance on the potential for flooding in the Fraser River Basin as far downstream as Hope.

Researchers at the University of British Columbia (UBC) are developing and calibrating hydrologic models using field study results from the province's Interior. These models explore changes in streamflow and the potential for flooding that result from extensive MPB-related forest cover loss and salvage harvesting in large watersheds, over long periods of time, and under diverse weather conditions.

- M. Weiler (formerly of UBC, now at the University of Freiburg) is leading a project to predict changes in peak flows resulting from the MPB infestation and salvage harvesting (Weiler *et al.* 2008). The model will avoid the need for complex data inputs and calibration procedures, which is a problem in remote, data-poor regions of the province.
- R.D. Moore (UBC Departments of Geography and Forest Resources Management) is leading a team to develop a new modelling approach for predicting the hydrologic effects of intense forest disturbance. The model structure will be flexible, take advantage of spatial data sets (e.g., digital elevation models and vegetation data) that use readily available meteorological data, and be computationally efficient.
- Y. Alila (UBC Department of Forest Resources Management) is leading a team to apply the physically based, data-intensive research model DHSVM at the Baker Creek watershed. The goal of this research is to integrate stand-level measurements into watershed-scale modelling and to further refine the data inputs and application of the DHSVM model.

Watershed Management Issues and Planning Recommendations

Changes in forest cover related to both the MPB infestation and salvage harvesting can influence stand and watershed hydrology by increasing the amount of water reaching, being stored along, and flowing from hillslopes. Increases in available water, surface runoff, and hillslope flow can:

- elevate water tables;
- stress existing drainage structures;
- increase surface erosion, including damage to forest road surfaces as well as cuts and fills;
- increase landslide activity;
- increase the magnitude and frequency of peak flows; and
- increase channel destabilization, particularly where woody debris recruitment has been reduced.

The consequences of these changes can include:

- loss of soil and site productivity;
- loss of fish habitat;
- reduced water quality;
- damaged property; and
- increased risk to public safety.

Both stand- and watershed-scale changes—immediate or otherwise—may be observed for many years, depending on the watershed and the weather. To mitigate the effects of the MPB infestation on water and watersheds, forest resource planners should consider the following general recommendations.

- Identify watersheds and values at risk.
- Salvage-log in stages using various cutting intensities and retention strategies distributed over the landscape to desynchronize runoff.
- Maintain a diversity of cover types and minimize post-salvage reforestation delays through single-tree or patch retention to protect advance regeneration and through retention of non-pine and broadleaved forest vegetation.
- Delay or interrupt surface runoff by leaving fine and coarse woody debris in openings where possible.
- Avoid sensitive terrain and soil types, and develop erosion control plans.
- Minimize harvesting within riparian areas, particularly in systems that depend on woody debris.
- Construct, inspect, and maintain roads to ensure that natural surface and shallow subsurface drainage remain intact both during and after salvage.
- Upgrade drainage networks on permanent roads before salvage harvesting as necessary to accommodate expected increases in peak flows.

Qualified hydrologists and geomorphologists should undertake watershed-specific assessments, particularly where extensive salvage harvesting is planned, where hydrologic change is expected, or where risks to infrastructure or public safety have been identified. Elevated risks to water values, infrastructure, and public safety as a result of changes in hydrologic and geomorphic processes in watersheds affected by MPB should be clearly communicated to all resource agencies and the public.

Ongoing Research Programs

New and ongoing research projects, both field- and model-based, are under way throughout the British Columbia Interior (Figures 3 and 6). These projects address questions about the effects of MPB-related stand mortality, salvage harvesting, partial retention, and regeneration on:

- snow accumulation and melt,
- stand water balances,
- streamflow,
- channel stability,
- riparian function,
- water quality, and
- aquatic habitat.

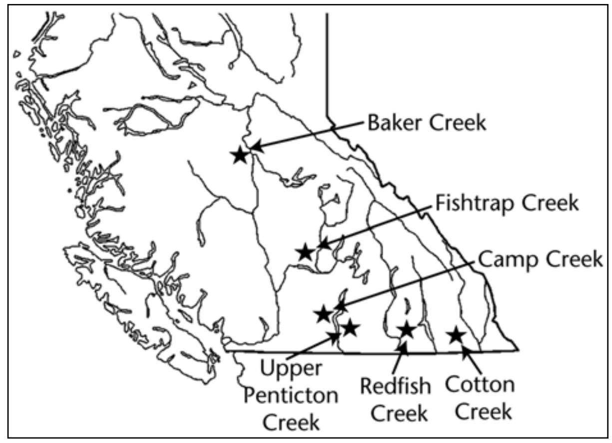

FIGURE 6. Ongoing watershed-scale research projects in the British Columbia Interior that are examining the effects of disturbance on hydrological processes and watershed response.

Research at Mayson Lake is examining mature and young stands as they deteriorate following MPB attack and wildfire. This study focusses on changes in the annual water balance including snow accumulation and melt, rainfall interception, evaporation, and soil moisture. Research into the effects of post–MPB-attacked stand structure on snow accumulation and melt is also being conducted in clearcuts, partially recovered clearcuts, recently attacked pine stands, and pine stands attacked 20 years ago throughout the Cariboo-Chilcotin and on the Nechako Plateau (Teti 2007).

In the Southern Interior, long-term investigations into the hydrologic effects of forest harvesting at Upper Penticton Creek and Redfish Creek, near Penticton and Nelson, respectively, are examining changes in water yield and quality. These long-term projects include stand-scale research focussed on specific hydrologic processes, such as the effects of forest cover on snow accumulation and melt, rainfall interception, evaporation, and soil moisture, as well as on watershed-scale changes in streamflow, channel morphology, water quality, and aquatic habitat. Modelling initiatives are complementing field projects at both locations.

Recently initiated watershed-scale projects include Baker Creek, Cotton Creek, and Fishtrap Creek. At Baker Creek, near Quesnel, monitoring of environmental variables is taking place to quantify hydrologic processes and to model changes in streamflow from heavy MPB attack in this large watershed and its sub-basins. In the Cotton Creek Watershed Experiment, near Cranbrook, hydrologic processes before MPB attacks have been monitored since 2004 and are used to quantify post-attack trends in watershed function (Redding *et al.* 2007a). Research at Fishtrap Creek, near Kamloops, is quantifying the effects of extensive wildfire on in-stream processes, water yield, and aquatic habitat.

Research in the upper Fraser and Nechako watersheds continues to investigate the effect of the MPB infestation and salvage harvesting on riparian zones and stream temperature. This work aims to identify the level of ecological function of small and large streams and their riparian zones over more than 20 years after large-scale harvesting. It is also addressing concerns about rising water tables and the loss of summer ground (i.e., dry soil capable of supporting heavy forest harvesting equipment without becoming excessively disturbed or compacted).

In the sub-boreal spruce forests north of Prince George, a team of researchers from UBC, the University of Northern British Columbia, the Ministry of Forests and Range, and the Canadian Forest Service are measuring water (transpiration and evaporation) and carbon fluxes as part of the Canadian Carbon Program FLUXNET Canada initiative. The stands undergoing measurement include two lodgepole pine stands between 80 and 100 years old that were attacked by MPB in 2004 and 2006, a 7-year-old clearcut with natural regeneration, and a 2-year-old clearcut that was salvage-logged and planted in 2006. More information on this study can be found at: *http://www.fluxnet-canada.ca/*

A UBC research team has initiated a project to evaluate the impact of pine beetle infestation on runoff generation and water quality in a regional context. The emphasis is on evaluating: hydrological changes; sediment generation; carbon, nitrate, and aluminum losses in the water; and differences in the litter composition and hydrophobicity relative to forest management. The monitoring will focus on seasonal effects and storm events (snow melt, storm events, summer low flow), and comparisons will be made within and between regions. The results will be incorporated into a decision-support model that will predict flow-regime changes and the effects on water quality. This model will assist managers in determining mitigation strategies for water supplies and for protecting ecosystem services. For more information, contact Sandra Brown, UBC Institute for Resources and Environment (*sjbrown@interchange.ubc.ca*).

New research results will improve our understanding of hydrologic response to extensive forest cover change and can be used to improve operational guidelines, watershed and risk assessment tools, and flood forecasts. These results will also have relevance in predicting the potential effects of climate change on forests, water supplies, and aquatic habitat. Consult the following websites for additional information about new and ongoing watershed research.

- The Bowron River Watershed Project (*http://www.for.gov.bc.ca/hre/ffip/Bowron.htm*)
- Prince George Small Streams Project (*http://www.for.gov.bc.ca/hre/ffip/PGSSP.htm*)
- Baker Creek Project (*http://www.forestry.ubc.ca/bakercreek*)
- Cariboo-Chilcotin Snow Research (*http://www.for.gov.bc.ca/rsi/research/snow.htm*; *http://people.uleth.ca/~sarah.boon/forest.html*)
- Upper Penticton Creek Watershed Experiment (*http://www.for.gov.bc.ca/rsi/research/Penticton/index.htm*)
- Fishtrap Creek Project (*http://www.geog.ubc.ca/~beaton/Fishtrap/Overview.html*)
- West Arm Demonstration Forest (Redfish Creek) (*http://www.for.gov.bc.ca/rsi/research/WADF/WADF.htm*)
- Cotton Creek Watershed Experiment (*http://www.forestry.ubc.ca/cottoncreek/*)

Sources of Further Information

In 2006, as part of an interagency flood hazard mitigation initiative, the Provincial Emergency Program produced a series of overview maps. The maps show all third-order and higher watershed boundaries, communities, public infrastructure, forests consisting of more than 40% lodgepole pine, and the area logged during the past 25 years over most of the Interior. Tables summarizing watershed area, the area of pine-dominated forest, and the area logged are also included. These maps and tables provide a useful indication of the extent of both lodgepole pine-leading forest types, where significant stand mortality is expected, and past disturbance. The maps are available at: *http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/stewardship/*

In 2007, the B.C. Ministry of Forests and Range initiated a project to identify the hydrologic risk of increased peak flow in selected towns and cities in areas affected by MPB. Risk will be assessed using the peak flow impact category of the Interior Watershed Assessment Procedure. The final report will be available in 2008.

Websites summarizing hydrologic processes and management approaches in response to MPB can be found at:

- B.C. Ministry of Forests and Range MPB main site (*http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/*)
- B.C. Ministry of Forests and Range recommended operational procedures to address hydrological concerns (*http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/stewardship/Hydrological%20Recommendations%20Dec%203%202004.pdf*)
- B.C. Ministry of Forests and Range Guidance on Landscape- and Stand-level Structural Retention in Large-Scale Mountain Pine Beetle Salvage Operations (*http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/stewardship/cf_retention_guidance_dec2005.pdf*)
- The Kamloops Forest Hydrology Abstracts Library includes abstracts of papers describing the effects of forest disturbance on water quantity and quality, providing an indication of the potential changes to be expected with MPB (*http://foresthydrology.gov.bc.ca/*)
- Presentations from the July 2007 workshop entitled "Mountain Pine Beetle and Watershed Hydrology Workshop: Preliminary Results of Research from

BC, Alberta and Colorado" are summarized by Redding and Pike (2007); the full proceedings are available from: *http://www.forrex.org/program/water/mpb_hydrology.asp*

- FORREX Forum for Research and Extension in Natural Resources maintains an information portal for information, publications, and events relating to MPB (*http://nrin.forrex.org/servlet/mpb*)
- The Canadian Forest Service's Mountain Pine Beetle Initiative web page includes general overview reports, as well as final project documents (*http://mpb.cfs.nrcan.gc.ca/publications_e.html*)

Conclusions

The potential effects of the MPB infestation and associated salvage harvesting include larger and earlier peak flows and impacts on water quality and aquatic habitat. Changes in flow regimes will be greatest in the short term where extensive salvage harvesting is applied. The changes in flows may have major implications for the design of infrastructure on the floodplain and highlights the need to plan the extent of clearcut salvage harvesting in infested watersheds, designate reserve areas, and carefully design stream crossings (Forest Practice Board 2007). Planning for retention at all scales (stand, watershed, and landscape) will be critical to protect watershed function and maintain flexibility for future management options. In addition, the effects of increased road construction on water quantity and quality are unknown at this time. The effects of roads include both direct effects (e.g., the potential for increased sedimentation) and also indirect effects related to greater human access to previously inaccessible areas.

The magnitude and rate of spread of the MPB infestation highlights the need to maintain long-term watershed research and monitoring capacity and infrastructure. Much of the information synthesized in this paper is based on results of studies that were not originally intended to address questions of MPB infestation impacts. The long-term data sources allow watershed specialists to inform forest management planning in a timely manner, and provide a rich legacy for responding to future disturbances, land use changes, and climate change.

The potential effects of the MPB infestation and associated salvage harvesting include larger and earlier peak flows and impacts on water quality and aquatic habitat.

References

Alila, Y. and C. Luo. 2007. Delineating the limits on peak flow and water yield responses to clearcut salvage logging in large watersheds. *In* Proceedings, Mountain Pine Beetle and Watershed Hydrology Workshop: Preliminary Results of Research from BC, Alberta and Colorado, July 10, 2007. T. Redding (editor). Kelowna, B.C. pp. 43–44. URL: *http://www.forrex.org/program/water/PDFs/Workshops/mpb/MPB-Hydrology_Workshop_Handbook.pdf*

Beaudry, P. 2007. Snow surveys in Supply Block F, Prince George TSA: January to March, 2007. Canadian Forest Products Ltd., Prince George Division, Prince George, B.C. Unpublished report.

Beaudry, P and L. Beaudry. Large woody debris dynamics. *In* Prince George Small Streams Project: A Five-Year Synthesis Report. J. Rex and D.A. Maloney (editors). B.C. Ministry of Forests and Range. Special Report Series. Forthcoming.

Bethlahmy, N. 1975. A Colorado episode: Beetle epidemic, ghost forests, more streamflow. Northwest Science 49(2):95–105.

Boon, S. 2007a. Snow accumulation and ablation in a beetle-killed pine stand in Northern Interior British Columbia. BC Journal of Ecosystems and Management 8(3):1–13. URL: *http://www.forrex.org/publications/jem/ISS42/vol8_no3_art1.pdf*

_______. 2007b. Impact of MPB infestation and salvage harvesting on seasonal snow melt and runoff. *In* Proceedings, Mountain Pine Beetle and Watershed Hydrology Workshop: Preliminary Results of Research from BC, Alberta and Colorado, July 10, 2007. T.

Redding (editor). Kelowna, B.C. pp. 13–14. URL: *http://www.forrex.org/program/water/PDFs/Workshops/mpb/MPB-Hydrology_Workshop_Handbook.pdf*

Carlyle-Moses, D. 2007. Preliminary findings on canopy and bryophyte forest floor interception loss of growing-season rainfall at Mayson Lake. *In* Proceedings, Mountain Pine Beetle and Watershed Hydrology Workshop: Preliminary Results of Research from BC, Alberta and Colorado, July 10, 2007. T. Redding (editor). Kelowna, B.C. pp. 23–24. URL: *http://www.forrex.org/program/water/PDFs/Workshops/mpb/MPB-Hydrology_Workshop_Handbook.pdf*

Cheng, J.D. 1989. Streamflow changes after clearcut logging of a pine beetle-infested watershed in southern British Columbia, Canada. Water Resources Research 25:449–456.

Dubé, S. and J. Rex. 2008. Hydrologic effects of mountain pine beetle infestation and salvage-harvesting operations. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. BC Journal of Ecosystems and Management 9(3):134. URL: *http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf*

Environmental Dynamics Inc. 2008. Mountain pine beetle infestation: Hydrological impacts. B.C. Ministry of Environment, Prince George, B.C. Unpublished report.

Forest Practices Board. 2007. The effect of mountain pine beetle attack and salvage harvesting on streamflows. Victoria, B.C. URL: *http://www.fpb.gov.bc.ca/special/investigations/SIR16/The_Effect_%20of_%20Mountain_%20Pine_%20Beetle_%20Attack_%20and_%20Salvage_%20Harvesting_%20on_%20Streamflows_SIR16.pdf*

Hélie, J.F., D.L. Peters, K.R. Tattrie, and J.J. Gibson. 2005. Review and synthesis of potential hydrologic impacts of mountain pine beetle and related harvesting activities in British Columbia. Natural Resources Canada, Canadian Forest Service, Victoria, B.C. Mountain Pine Beetle Initiative Working Paper 2005–23. URL: *http://warehouse.pfc.forestry.ca/pfc/25684.pdf*

Huggard, D. and D. Lewis. 2007. Summary of ECA effects of options for mountain pine beetle salvage: Stand and watershed level reports. B.C. Ministry of Environment, Kamloops, B.C. Unpublished report.

Johannes, M.R.S., A. Kenney, J. Pouliotte, and D. Steele. 2007. Mountain pine beetle threats to salmon and fisheries resources in BC: Proceedings of the Pacific Salmon Foundation and Fraser Basin Council Workshop. January 30–31, 2007, Prince George, B.C. Golder Associates Ltd., Vancouver, B.C.

Landhausser, S.M., V.J. Lieffers, and U. Silins. 2003. Utilizing pioneer species as a hydrological nurse crop to lower water table for reforestation of poorly drained boreal sites. Annals of Forest Science 60:741–748.

Lin, Y. and X. Wei. 2008. The impact of large-scale forest harvesting on hydrology in the Willow Watershed of Central British Columbia. Journal of Hydrology 359:141–149.

Megahan, W.F. 1983. Hydrologic effects of clearcutting and wildfire on steep granitic slopes in Idaho. Water Resources Research 19:811–819.

Mellina, E. 2006. Stream temperature responses to clearcut logging in the central interior of British Columbia: Test of a predictive model developed by Mellina *et al.* (2002). Natural Resources Canada, Canadian Forest Service, Victoria, B.C. Mountain Pine Beetle Initiative Working Paper 2006-08. URL: *http://www.dpp.scf.rncan.gc.ca/archive/projects/3-21_e.html*

Mellina, E., R.D. Moore, S.G. Hinch, J.S. Macdonald, and G. Pearson. 2002. Stream temperature responses to clear-cut logging in British Columbia: The moderating influences of groundwater and headwater lakes. Canadian Journal of Fisheries and Aquatic Science 59:1886–1900.

Moore, D., R. Winkler, D. Carlyle-Moses, D. Spittlehouse, T. Giles, J. Phillips, J. Leach, B. Eaton, P. Owens, E. Petticrew, W. Blake, B. Heise, and T. Redding. 2008. Watershed response to the McLure forest fire: Presentation summaries from the Fishtrap Creek Workshop, March 2008. Streamline Watershed Management Bulletin 12(1):1–11. URL: *http://www.forrex.org/publications/streamline/ISS39/Streamline_Vol12_No1_art1.pd*f

Moore, R.D. and D.F. Scott. 2005. Camp Creek revisited: Streamflow changes following salvage harvesting in a medium-sized, snowmelt-dominated catchment. Canadian Water Resources Journal 30(4):331–344.

_______. 2006. Response to comment by P.F. Doyle on "Camp Creek revisited: Streamflow changes following salvage harvesting in a medium-sized, snowmelt-dominated catchment." Canadian Water Resources Journal 31(2):1–4.

Moore, R.D., D.G. Hutchinson, and M. Weiler. 2007. Predicting the effects of post-MPB salvage harvesting using a conceptual streamflow model (HBV-EC): Initial evaluation using a paired catchment approach. *In* Proceedings, Mountain Pine Beetle and Watershed Hydrology Workshop: Preliminary Results of Research from BC, Alberta and Colorado, July 10, 2007. T. Redding (editor). Kelowna, B.C. pp. 41–42. URL: ***http://www.forrex.org/program/water/PDFs/Workshops/mpb/MPB-Hydrology_Workshop_Handbook.pdf***

Moore, R.D., D. Spittlehouse, and A. Story. 2005. Riparian microclimate and stream temperature response to forest harvesting: A review. Journal of the American Water Resources Association 41:813–834.

Nordin, L. 2008. The Bowron River Watershed: A synoptic assessment of stream and riparian condition 20–30 years after salvage logging. B.C. Ministry of Forests, Victoria, B.C. Extension Note No. 86. URL: ***http://www.for.gov.bc.ca/hfd/pubs/Docs/En/En86.htm***

Pike, R.G., T.E. Redding, D. Wilford, R.D. Moore, G. Ice, M. Reiter, and D.A.A. Toews. Detecting and predicting changes in watersheds. *In* Compendium of forest hydrology and geomorphology in British Columbia. R.D. Moore, R.G. Pike, and R.D. Winkler (editors). B.C. Ministry of Forests and Range, Research Branch, Victoria, B.C. and FORREX Forum for Research and Extension in Natural Resources, Kamloops, B.C. Forthcoming. URL: ***http://www.forrex.org/program/water/PDFs/Compendium/Compendium_Chapter14.pdf***

Pothier, D., M. Prevost, and I. Auger. 2003. Using the shelterwood method to mitigate water table rise after forest harvesting. Forest Ecology and Management 179:573–583.

Potts, D.F. 1984. Hydrologic impacts of a large-scale mountain pine beetle (*Dendroctonus ponderosae* Hopkins) epidemic. Water Resources Bulletin 20(3):373–377.

Redding, T. and R. Pike. 2007. Mountain pine beetle and watershed hydrology: Workshop summary. Streamline Watershed Management Bulletin 11(1):17–24. URL: ***http://www.forrex.org/publications/streamline/ISS36/streamline_vol11_no1.pdf***

Redding, T., D. Gluns, and D. Moore. 2007a. The Cotton Creek Watershed Experiment: Investigating the effects of forest disturbance on watershed function. LINK 9(2):4–5. URL: ***http://www.forrex.org/publications/link/ISS46/vol9_no2_art2.pdf***

Redding, T., R. Pike, and P. Teti. 2007b. Understanding the effects of mountain pine beetle and salvage harvesting on hydrological processes and watershed response. *In* Overcoming Obstacles to Variable Retention in Forest Management: Science to Management Forum Proceedings, September 25–27, 2007. BC Journal of Ecosystems and Management 8(3):149. URL: ***http://www.forrex.org/publications/jem/ISS42/vol8_no3_scienceforum.pdf***

Redding, T., R. Winkler, D. Carlyle-Moses, and D. Spittlehouse. 2007c. Mayson Lake study examines hydrological processes. LINK 9(2):10–11. URL: ***http://www.forrex.org/publications/link/ISS46/vol9_no2_art4.pdf***

Rex, J. 2007. MPB, riparian retention, and the loss of summer ground: An overview of projects from the Central Interior. *In* Proceedings, Mountain Pine Beetle and Watershed Hydrology Workshop: Preliminary Results of Research from BC, Alberta and Colorado, July 10, 2007. T. Redding (editor). Kelowna, B.C. pp. 29–30. URL: ***http://www.forrex.org/program/water/PDFs/Workshops/mpb/MPB-Hydrology_Workshop_Handbook.pdf***

Rex, J. and S. Dubé. 2006. Predicting the risk of wet ground areas in the Vanderhoof Forest District: Project description and progress report. BC Journal of Ecosystems and Management 7(2):57–71. URL: ***http://www.forrex.org/publications/jem/ISS35/vol7_no2_art7.pdf***

Rothwell, R.L. and R.H. Swanson. 2007. Hydrologic effects of mountain pine beetle infestations in western Alberta. *In* Proceedings, Mountain Pine Beetle and Watershed Hydrology Workshop: Preliminary Results of Research from BC, Alberta and Colorado, July 10, 2007. T. Redding (editor). Kelowna, B.C. pp. 39–40. URL: ***http://www.forrex.org/program/water/PDFs/Workshops/mpb/MPB-Hydrology_Workshop_Handbook.pdf***

Schmid, J.M., S.A. Mata, M.H. Martinez, and C.A. Troendle. 1991. Net precipitation within small group infestations of the mountain pine beetle. U.S. Department of Agriculture Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Colllins, Colo. Research Note No. RM-508.

Schnorbus, M. 2008. Quantifying the hydrologic impacts of mountain pine beetle and associated salvage operations in the Fraser River watershed. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. BC Journal of Ecosystems and Management 9(3):135. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Silins, U., V. Lieffers, D. Reid, B. Brabendar, K. Bladon, and P. Pina. 2007. Stand water balance in absence of mountain pine beetle: Synthesis of several Alberta studies to characterize "reference" water use of lodgepole pine. *In* Proceedings, Mountain Pine Beetle and Watershed Hydrology Workshop: Preliminary Results of Research from BC, Alberta and Colorado, July 10, 2007. T. Redding (editor). Kelowna, B.C. pp. 21–22. URL: ***http://www.forrex.org/program/water/PDFs/Workshops/mpb/MPB-Hydrology_Workshop_Handbook.pdf***

Spittlehouse, D. 2007. Influence of the mountain pine beetle on the site water balance of lodgepole pine forests. *In* Proceedings, Mountain Pine Beetle and Watershed Hydrology Workshop: Preliminary Results of Research from BC, Alberta and Colorado, July 10, 2007. T. Redding (editor). Kelowna, B.C. 25–26. URL: ***http://www.forrex.org/program/water/PDFs/Workshops/mpb/MPB-Hydrology_Workshop_Handbook.pdf***

Spittlehouse, D.L. and R.D. Winkler. 2004. Snowmelt in a forest and clearcut. *In* Proceedings 72nd Western Snow Conference, April 19–22, 2004, Richmond, B.C. pp. 33–43.

Stednick, J. 2007. Preliminary assessment of water quantity and quality changes in beetle-killed catchments in north-central Colorado. *In* Proceedings, Mountain Pine Beetle and Watershed Hydrology Workshop: Preliminary Results of Research from BC, Alberta and Colorado, July 10, 2007. T. Redding (editor). Kelowna, B.C. pp. 27–28. URL: ***http://www.forrex.org/program/water/PDFs/Workshops/mpb/MPB-Hydrology_Workshop_Handbook.pdf***

Teti, P. 2007. Solar radiation and snow ablation in natural and managed pine stands. *In* Proceedings, Mountain Pine Beetle and Watershed Hydrology Workshop: Preliminary Results of Research from BC, Alberta and Colorado, July 10, 2007. T. Redding (editor). Kelowna, B.C. pp. 17–18. URL: ***http://www.forrex.org/program/water/PDFs/Workshops/mpb/MPB-Hydrology_Workshop_Handbook.pdf***

Teti, P. and R. Winkler. 2008. Snow and solar radiation in growing and deteriorating pine stands. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. BC Journal of Ecosystems and Management 9(3):136–138. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Tripp, D.B., P.J. Tschaplinski, S.A. Bird, and D.L. Hogan. 2008. Protocol for evaluating the condition of streams and riparian management areas (riparian management routine effectiveness evaluation). Forest and Range Evaluation Program, B.C. Ministry of Forests and Range and B.C. Ministry of Environment, Victoria, B.C. URL: ***http://www.for.gov.bc.ca/hfp/frep/site_files/indicators/Indicators-Riparian-Protocol-2008.pdf***

Troendle, C.A. and J.O. Ruess. 1997. Effect of clear cutting on snow accumulation and water outflow at Fraser, Colorado. Hydrology and Earth System Sciences 1:325–332.

Uunila, L., B. Guy, and R. Pike. 2006. Hydrologic effects of mountain pine beetle in the interior pine forests of British Columbia: Key questions and current knowledge. Streamline Watershed Management Bulletin 9(2):1–6. URL: ***http://www.forrex.org/publications/streamline/ISS31/streamline_vol9_no2.pdf***

Wei, A. and Y. Lin. 2007. Evaluation of the impacts of large-scale forest disturbance on hydrology in the BC interior. *In* Proceedings, Mountain Pine Beetle and Watershed Hydrology Workshop: Preliminary Results of Research from BC, Alberta and Colorado, July 10, 2007. T. Redding (editor). Kelowna, B.C. pp. 33–34. URL: ***http://www.forrex.org/program/water/PDFs/Workshops/mpb/MPB-Hydrology_Workshop_Handbook.pdf***

Wei, A., X. Chen, and R. Scherer. 2007. Assessment of the impacts of wildfire and MPB infestation on in-stream wood recruitment and transportation processes in the BC Interior. *In* Proceedings, Mountain Pine Beetle and Watershed Hydrology Workshop: Preliminary Results of Research from BC, Alberta and Colorado, July 10, 2007. T. Redding (editor). Kelowna, B.C. pp. 53–54. URL: ***http://www.forrex.org/program/water/PDFs/Workshops/mpb/MPB-Hydrology_Workshop_Handbook.pdf***

Weiler, M., K. Rosin, and C. Scheffler. 2008. Development of a hydrologic process model for mountain pine beetle-affected areas in British Columbia. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. BC Journal of Ecosystems and

Management 9(3):139. URL: *http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf*

Winkler, R.D. 2007. Snow accumulation and melt in southern interior lodgepole pine forests. *In* Proceedings, Mountain Pine Beetle and Watershed Hydrology Workshop: Preliminary Results of Research from BC, Alberta and Colorado, July 10, 2007. T. Redding (editor). Kelowna, B.C. pp. 19–20. URL: *http://www.forrex.org/program/water/PDFs/Workshops/mpb/MPB-Hydrology_Workshop_Handbook.pdf*

Winkler, R. and J. Roach. 2005. Snow accumulation in B.C.'s southern interior forests. Streamline Watershed Management Bulletin 9(1):1–5. URL: *http://www.forrex.org/publications/streamline/ISS30/streamline_vol9_no1.pdf*

Winkler, R., D. Gluns, and D. Golding. 2004. Identifying snow indices for forest planning in southern British Columbia. *In* Proceedings 72nd Western Snow Conference, April 19–22, 2004, Richmond, B.C. pp. 53–61.

Winkler, R.D., D.L. Spittlehouse, and D.L. Golding. 2005. Measured differences in snow accumulation and melt among clearcut, juvenile, and mature forests in southern British Columbia. Hydrological Processes 19:51–62.

Winkler, R.D., R.D. Moore, T.E. Redding, D.L. Spittlehouse, D. Carlyle-Moses, and B. Smerdon. Hydrologic processes and watershed response. *In* Compendium of forest hydrology and geomorphology in British Columbia. R.G. Pike, T.E. Redding, R.D. Moore, and R.D. Winkler (editors). B.C. Ministry of Forests and Range, Research Branch, Victoria, B.C. and FORREX Forum for Research and Extension in Natural Resources, Kamloops, B.C. Forthcoming.

Winkler, R.D., J. Rex, P. Teti, D. Maloney, and T. Redding. 2008. Mountain pine beetle, forest practices, and watershed management. B.C. Ministry of Forests and Range, Research Branch, Victoria, B.C. Extension Note No. 88. URL: *http://www.for.gov.bc.ca/hfd/pubs/Docs/En/En88.pdf*

Thematic Session Synthesis

Socio-economic impact of the mountain pine beetle

Dan Orcherton[1]

Abstract

Over the past decade, the mountain pine beetle (MPB) has been in the hearts and minds of most people throughout its geographic range. This infestation is regarded as a catastrophic natural disaster in British Columbia, causing widespread mortality of lodgepole pine. It has also placed forest values at risk and threatens social, community, and cultural stability as well as the long-term economic well-being of many northern communities in the province. This paper explores strategies that have been developed to address the socio-economic impacts of the MPB and the lessons learned. Finding economically viable, socially adoptable, and culturally acceptable solutions to the MPB problem still suffers from research and information gaps. Identifying important socio-ecological resilience factors and viable socio-economic linkages between communities and the landscape is a fundamental enabling strategy for more effective dialogue between First Nations people, resource managers, community leaders, residents, and the science community. With the inevitable appropinquation of climate change, communities must diversify (e.g., non-timber forest products, agroforestry) to provide sustainable socio-economic alternatives for future generations.

KEYWORDS: *climate change, community responses, First Nations perspectives, gender perspectives, mountain pine beetle impacts, non-timber forest products, socio-ecological resilience, socio-economics.*

Contact Information

1 Extension Research Associate (Socio-Economics), FORREX, c/o Ecosystems Science and Management Program, College of Science and Management, University of Northern British Columbia, 3333 University Way, Prince George, BC V2N 4Z9. Email: Dan.Orcherton@forrex.org

Orcherton, D. 2008. Socio-economic impact of the mountain pine beetle. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):51–59. URL: *http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf*

Introduction

Over the past decade, the mountain pine beetle (MPB) has been in the hearts and minds of most people throughout its geographic range in British Columbia. Regarded as a catastrophic natural disaster, this infestation has caused widespread mortality of lodgepole pine and has also placed forest values at risk, threatening social, community, and cultural stability as well as the long-term economic well-being of many northern communities in the province. This paper explores the problem in context by examining strategies that have been developed to address the socio-economic impacts of the MPB and the lessons learned. Identifying important socio-ecological resilience factors and viable socio-economic linkages between communities and the landscape is a fundamental enabling strategy for more effective dialogue between First Nations people, resource managers, community leaders, residents, and the science community. Finding economically viable, socially adoptable, and culturally acceptable solutions to the MPB problem still suffers from research and information gaps.

The Socio-economics Concurrent Session formed part of the Mountain Pine Beetle: From Lessons Learned to Community-Based Solutions conference, held June 10–11, 2008, at the University of Northern British Columbia, Prince George, B.C. This session highlighted 12 sub-themes related to the MPB.[1] This paper provides a summary of nine sub-themes. Other conference presenters outlined additional critical areas of consideration when dealing with MPB-affected stands, such as First Nations cultural and societal values, and fibre opportunities and manufacturing (see, for example, synthesis papers by Thomas [page 60] and Parisotto [page 71]).

Climate Change

Summary

The interior region of British Columbia is experiencing the most extensive MPB outbreak ever recorded in North America. This infestation is linked to changing climate conditions and forest management policies

Identifying important socio-ecological resilience factors and viable socio-economic linkages between communities and the landscape is a fundamental enabling strategy for more effective dialogue between First Nations people, resource managers, community leaders, residents, and the science community.

that have resulted in a large number of mature, even-aged, pine trees. Because of the dominance of the forest industry in this region, the MPB outbreak will have significant socio-economic impacts on forest-dependent communities.

One of the more interesting, yet least understood topics, is metagovernance and the adaptation strategies of several communities affected by the MPB outbreak (Parkins 2008). Parkins' study highlights metagovernance as a compelling opportunity to expand analysis of institutional adaptation to climate-induced environmental challenges. Metagovernance offers a framework for theory-building and empirical analysis that links local political activity with hierarchical structures; however, the utility of metagovernance as a tool for enlarging state competencies remains an open question and one that requires further empirical exploration (Parkins 2008). At best, metagovernance may improve our understanding of institutional adaptation and the challenges of co-ordination, negotiation, and collaboration within and between private and public institutions as they respond to the MPB outbreak (Parkins 2008).

Parkins' study drew on experiences in northern communities within a broader social and economic context, and emphasized institutional innovation as a form of metagovernance. This is often associated with vulnerability to climate change and a host of

[1] National/regional/local conferences; research synthesis and strategy forums; gender perspectives and MPB; non-timber forest products; social and cultural impacts; socio-economics and community vulnerability; socio-ecological resilience; user surveys and public perception surveys; economics and institutional impacts; climate change and its associated socio-economic impacts; socio-economic working groups, regional and community-based responses to MPB; document summaries; review of current programs and projects.

other challenges facing communities within this region (Parkins 2008). The use of pilot projects was also emphasized for climate change programming and research endeavours, especially related to MPB follow-up monitoring. Decision-support systems and modelling scenarios could also be used to examine the potential for MPB spread and attack under different climate change scenarios. Studies under this theme emphasized vulnerability assessments, and the need to have stakeholder-driven community assessments.

Key Lessons Learned

- Climate change is a critical determining factor when considering institutional adaptation to the MPB in British Columbia.
- Climate change has significant implications for stability of ecosystems and cultural well-being of communities.
- Certain protected areas clearly illustrate the connection between climate change and ecosystem impacts.
- Public messaging is important to inform the public about climate change. The message should not be strong or negative, but practical and realistic in nature.
- Adaptive capacity[2] of the forest sector in northern British Columbia is likely to be high. Further tests need to be rigorous enough to advocate national forest sector vulnerability assessments. Stakeholder-driven participatory monitoring and evaluation processes need to be implemented.
- It is important to recognize a local community's capacity to adapt to shocks or stresses and to acknowledge (or include) inherent features and properties of social and cultural systems (e.g., human capital and social capital), policy and institutional factors, awareness, and processes by which risk perceptions are socially constructed and locally implemented.

Regional and Community-based Responses to the Mountain Pine Beetle Outbreak

Summary

Community-based responses to MPB rely intuitively on the notion of implementing strategically aligned adaptive management processes and collaborative linkages. This can be accomplished through the development and inclusion of socio-economics working groups, task forces, fora, or discussion groups. These activities usually engage multiple-interest groups and provide policy approaches that assist in resolving issues and concerns through prescriptive or adaptive management alternatives or actions.

Most of the community-based responses have been shared among the various Beetle Action Coalitions (BACs): the Cariboo-Chilcotin Beetle Action Coalition (CCBAC), the Omineca Beetle Action Coalition (OBAC), and the Southern Interior Beetle Action Coalition (SIBAC), as well as the First Nations Mountain Pine Beetle Initiative (FNMPBI). FORREX and volunteers from numerous partner organizations also contributed to the Socio-Economics Extension Working Group (SEEWG), which looks at the importance and on-the-ground implementation of decision-support tools, economic analyses, extension programs and projects, as well as community protection, sustainable economies and cultures, and community stewardship. The SEEWG will review and redraft an updated 5-year plan and annual plans in the coming months.

The SIBAC has centred its efforts on community discussion and information gathering about concerns and expectations related to the MPB outbreak. Stakeholder engagement and community/committee consultation has started, and the group has just begun the process of preparing a community-based response to the MPB outbreak. Reports will be completed over the next months. This group maintains a significant interior network of First Nations support councils, regional district managers, tribal councils, and others.

The OBAC has compiled a work plan summary and submitted a 2007–2008 Business Plan (Omineca Beetle Action Coalition 2007). The work plan was prepared to

[2] Capacity of a system to adapt if the environment where the system exists is changing.

meet the broader commitments that coalition members made to the provincial government, and to regional communities and partners. This group is working to ensure sustainable development and resiliency in its region by: gathering and sharing credible information; partnering with senior levels of government and industry to communicate on community interests regarding beetle outbreak and economic diversification issues; developing policy positions and advice to influence decisions that support sustainable development; following up with policy and decision makers about senior government commitments to the region; and influencing government and corporate policy and decision-support systems. The group has also recently developed a Minerals and Mining Sector Strategy (Omineca Beetle Action Coalition 2007), which was approved May 14th (Omineca Beetle Action Coalition 2008). This is one of 12 strategies the group will develop to identify actions required by all levels of government, First Nations, and industry leaders in support of the responsible and sustainable growth of mineral exploration and mining development in the OBAC region. To facilitate operational activities, it is important that FORREX and its partners align with this Strategy.

The CCBAC currently relies on a 2005–2006 Business Plan (Cariboo-Chilcotin Beetle Action Coalition 2007) that: encourages long-term economic sustainability for communities affected by the MPB outbreak; maintains and protects public health, safety, and infrastructure; recovers the greatest value from dead timber; and conserves the long-term forest values identified in the land use plans. The CCBAC is also obliged to prevent and reduce damage to forests in areas that are susceptible to the MPB and to restore forest resources in areas affected by the outbreak. The group is currently awaiting government approval of their final comprehensive strategy.

In November 2006, the First Nations Mountain Pine Beetle Interim Working Group identified 99 First Nations' bands in its initial analysis (B.C. First Nations Pine Beetle Action Plan 2006). It is estimated that 58 682 people are, or will be experiencing, impacts to their traditional economies and lifestyles and local mainstream economies as a result of the MPB outbreak.

The program is being administered through Community Futures Development Corporation of the Central Interior First Nations and will offer the working group a database of information to better determine the best use of program funding. Current funding will terminate in March 2009. Tentatively, the First Nations Forestry Council will take over operations from the FNMPBI after this date.

Key Lessons Learned

- Better legislation and carbon management policies in British Columbia are necessary. This would help in managing areas affected by the MPB.
- Developing a social sciences curriculum (topics and modules), and follow-up workshops are necessary to help reinforce FORREX and partners extension needs, priorities, and opportunities (including potential collaborations).

User Surveys, Public Perception Surveys, and Awareness Building About Mountain Pine Beetle

Summary

The majority of the public perception surveys and awareness building about MPB was collected via mail surveys of the general public and resource users. Studies encompassing public perceptions of natural disturbance (particularly related to MPB) favoured public attitudes, knowledge, management preferences, and analysis of socio-ecological risk and forest biodiversity. Public advisory groups' views about local attitudes, tools, and processes were also examined. Surprisingly, public perceptions were often influenced by cognitive factors (value orientation and building of knowledge-based systems).

Key Lessons Learned

- Public beliefs about the origin of MPB events and how these framed appropriate management goals, post-events, and prescriptions of impacts and associated mitigation strategies, were important considerations in building awareness about MPB.
- Proactive approaches in uninfected forests were not generally supported. Issue salience and knowledge were the best predictors of attitudes toward MPB.
- The value orientation was a better predictor of prescriptions of risk and perceived effectiveness of conservation strategies than knowledge indicators or socio-cultural variables.
- The MPB was rated as posing a greater risk to health and productivity of park ecosystems than anthropogenic hazards and other natural disturbance agents. Knowledge and residency were important predictors of risk judgements.

- Public debate and discussion play a vital role in the management of natural resources; more effective outreach efforts are required to increase people's knowledge and to strengthen their confidence when discussing forest issues, particularly MPB.
- Although people's willingness to accept unspecified short-term negative impacts on other resource values (to address the MPB outbreak), public transparency is improved by demonstrating effective management efforts (focussed on addressing infestation).

Socio-economic Analysis and Institutional Impacts

Summary

Studies presented under this sub-theme highlighted the importance of direct or indirect socio-economic implications of the MPB outbreak. Mitigation strategies tend to reduce negative social and economic impacts.

Studies have centred on the ecological legacies of the current beetle outbreak and on the effects of alternate beetle control measures. Research has also identified the economic impact sensitivity in communities. This work was based on general equilibrium models that were constructed for each region to provide an indicator of economic vulnerability to infestation. One important process is the development of bio-energy options for MPB-attacked wood. Several attempts have been made to quantify beetle-killed wood as a biofuel feedstock for production of electricity. This presents promising investment opportunities, particularly if it supports a broad strategic vision for community betterment and sustainable growth for future generations.

Key Lessons Learned

- Simulations of future economic indicator levels under different scenarios are commonplace in the literature, but should be examined in terms of overall impacts.
- Computational general equilibrium models allow the simulation of future indicator levels of MPB.
- The degree to which impacts are reduced in each region depends on assumptions about forest regeneration and growth and in terms of reciprocal wood flow agreements.
- In typical endemic beetle population conditions, beetle-proofing is a form of preventative maintenance used to maintain the economic viability of forest stands susceptible to MPB infestation.
- Some policies governing resource use have been adapted to mitigate economic and social issues resulting from MPB infestation. (e.g., social impact assessments targeting MPB-affected communities; social valuation studies [Prince George], and the B.C. First Nations Forestry Council's joint land-use planning protocol). Much work is yet to be done in this area.
- Forest managers are still limited in their ability to easily access the effects of alternative MPB management strategies on wildlife and sustainable forest management indicators.

National/Regional/Local Conferences, Research Syntheses, Research Strategies, Fora, Reports, and (or) Action Plans

Summary

Throughout British Columbia, approximately 13 formal (or informal) fora, symposia, and conferences related to the MPB were held between 2001 and 2008. Socio-economic related reports and (or) action plans provided syntheses, or strategic summaries or assessments, of key factors influencing MPB-affected communities. Although the conferences, seminars, and fora showcased a reasonable overview of current situations and support methods (tools and strategies), underlying institutional or organizational barriers remain to accessing information as well as follow-up on lessons learned in these processes. The University of British Columbia/University of Northern British Columbia Research Synthesis and Strategy Forum (November 2007) highlighted concrete recommendations and gaps about the future forests of British Columbia, particularly related to resource-based communities. Specific barriers were addressed at different levels (e.g., in agroforestry production opportunities; community-based socio-economic diversification strategies for forest- and wood-based industries; value-added product development and commercialization on agricultural lands; and legislation, policy, regulations, and land tenure). This forum also included abstracts summarizing how social scientists, decision makers, and practitioners link broader-scale socio-economic concerns to communities in transition.

The Managing for Tomorrow Conference (May 2004) highlighted the disjuncture between Western science and traditional knowledge. This topic surfaced as an important concern for First Nations communities and researchers and social scientists who wish to jointly incorporate Aboriginal knowledge into decision making. A shift away from an exclusive focus on Western science is needed to accept a more integrated/holistic form of research and to encourage extension-related activities associated with co-operation and improved communication with First Nations groups and leaders.

The Ministry of Forests and Range MPB Stewardship Research Strategy (B.C. Ministry of Forests and Range 2005) is a high-level document that addresses stewardship knowledge gaps with a focus on the Chief Forester's highest priorities. Although many strategies for research have been implemented, a concern still remains about balancing social values and preferences with economic concerns in local communities to provide more resilient management strategies.

Most of these seminars and conferences have promulgated strategies and approaches to encourage or promote immediate actions and (or) long-term economic sustainability strategies. This is perhaps preferable to top-down management structures that are generally difficult to implement and monitor without adequate funding or support from partner organizations already engaged or doing the work. Providing solid knowledge-based solutions to the MPB infestation relies on consistency, follow-up, monitoring, and (or) migration of results.

Key Lessons Learned

- The forest sector is undergoing a fundamental transformation with major implications for the future of forest-dependent communities. Concise, consistent, and effective mechanisms are needed that foster sustainable partnerships and collaborative efforts in communities.
- Forest-dependent communities must seek traditional and alternative economic activities to maintain their livelihoods. If communities are to retain a sense of place and to become resilient over time, this will require the promotion of diverse socio-economic activities that blend with the social/cultural realities of each region.
- Asking hard questions deserves more inclusive answers. Barriers to information can be overcome by community-driven collaborative partnerships, adaptive management (learning by doing approaches), and even broader-based integrated resource management strategies that help address the range of community needs and opportunities.
- The needs of communities in transition must take precedence to improve community self-reliance and socio-economic sustainability. Communities must rely on local success stories, working models, and case studies that "demonstrate" or " teach" other communities productive and sustainable paths forward.
- Ministry of Forests and Range Stewardship Research strategies (B.C. Ministry of Forests and Range 2005) are useful in identifying research knowledge gaps, so long as the environment and ecosystem approach can be seen (essentially) from a First Nations perspective. For example, First Nations values, ideals, belief structures, and holistic thinking should be interwoven and incorporated into strategies, programs, and project planning as MPB-related planning and implementation activities continue.

Gender Perspectives and the Mountain Pine Beetle

Summary

An important component of socio-economic and cultural research and extension is the recognition/inclusion and understanding of gender perspectives into most natural resource management plans, programs, and projects.

Boom, Bust, and Beyond: A Forum on Women's Perspectives on the Mountain Pine Beetle (University of Northern British Columbia, Northern Women's Centre, March 28–29, 2008) was an important outreach endeavour. The Forum highlighted gender perspectives in natural resource management, a perspective that is often overlooked. As the roles and responsibilities of women are often undervalued and (or) misunderstood, the forum provided a unique opportunity for women to focus their attention on the social, cultural, economic, institutional, and health-related impacts on beetle-affected communities in northern British Columbia. An important goal was to identify actions/steps to address and hopefully lessen the effects of the MPB on women and families in northern communities. The event helped to: demonstrate why and how the outbreak requires a gendered approach to fully understand its impacts; identify present and future strategies/responses to the beetle; equip participants with preliminary knowledge, understanding, and tools to influence decisions back in their communities; and identify community-based research opportunities, utilizing gender and diversity lenses, to broaden the scope of gender analysis in the field. Conclusions drawn from the forum highlighted a fundamental need for ecologists, economists, social scientists, and health researchers to integrate perspectives of women's roles and responsibilities within the natural resource sector, especially in beetle-affected communities (Orcherton *et al*. 2008).

Key Lessons Learned

- There is a real need to clearly define gender within the context of natural resource management, and to engage practitioners in the diversity of themes associated with gender.
- Implementing on-the-ground activities/ opportunities, which welcome women's perspectives in aspects of natural resource planning and development, could help achieve a gender balance and add quality of life.
- Successful integration of First Nations insights and understanding of traditional ecological knowledge and the incorporation of gender perspectives is a fundamental link within a holistic management perspective for MPB.
- Improving existing networks and organizational links helps foster improved communication and public consultation with hard-to-reach, vulnerable, or disadvantaged groups.
- In efforts to restructure rural communities, social cohesion draws on community/ecological capital by integrating perspectives of women's roles and responsibilities, helping to strengthen community socio-ecological resilience.
- To ensure a more all-encompassing approach, women's voices and experiences need to be better incorporated into the ongoing planning process for community and socio-economic development, particularly in MPB-affected communities.

Non-Timber Forest Products and the Mountain Pine Beetle

Summary

Non-timber forest products (NTFPs) represent one of the more important socio-economic areas for producing cultural, socio-economic, and ecosystem services, overlapping with a rapidly growing market sector. However, the issues and concerns surrounding NTFPs within MPB-affected areas are less well known, and require a specialized blend of traditional ecological knowledge and Western science to ascertain, document, and disseminate many of the complexities related to this sector. Non-timber forest products are generally considered to be economically important in the province, but little has been written or presented as a result of research or findings related to MPB areas. Most studies have been undertaken in relatively isolated locations guided by a handful of "experts" within provincially funded programs and projects. Although direct involvement by First Nations in the NTFP sector is perceived as inclusive, it may be of lesser importance, especially in the recognition of traditional resource rights, intellectual property, and involvement of Aboriginal-lead research projects or researchers. Some work has highlighted the importance of an all-inclusive or more holistic approach to NTFP research. This approach needs to overlap with First Nations traditions and values, and reflect the fundamental importance of indigenous property rights coinciding with traditional ecological knowledge. Also, most NTFP studies tend to be site specific, and do not easily translate to other areas. Dichotomies still exist between Western science-led ethnobotanical, anthropological, or ecological assessments and First Nations traditional or indigenous science. This often foments methodological conundrums that are not easily translated in the field.

Non-timber values, issues, and concerns centred on the impacts of other resource uses on traditional foods and medicines, commercialization of traditional foods and medicines, intellectual rights to indigenous knowledge, harvest practices (e.g., pine mushrooms), and lack of information and support to allow NTFP management by First Nations.

Key Lessons Learned

- No adequate method is available to incorporate NTFPs within vegetation inventories.
- To help address remediation of effects and guide restoration efforts, the distribution, abundance, and quantity of the species within MPB-affected areas should be compared with non-affected areas or historical data to understand the effect of MPB on the understorey (particularly NTFPs).
- Timber and non-timber uses of paper birch, offer promising alternatives, but more work should be done developing socio-economic models, cost-benefit and feasibility studies to warrant funding efforts and demonstration plots, particularly in northern British Columbia.

Socio-economics and Community Stability or Vulnerability, and Socio-ecological Resilience

Summary

This was one of the conference's "hot topics." Several presenters contributed to this theme, with the general understanding/consensus, that:

- Communities (and inhabitants within) are living, breathing entities that can become susceptible (vulnerable) to downturns in economic and social circumstances over time. Community stability/vulnerability is dictated by local, regional, national, and international market structures, policy reform, institutional and organizational strategies, and inherent community resilience to shocks and stresses.
- Comprehensive decision-support systems that explicitly address both social and environmental dimension of MPB are essential.
- Decision-support systems should be applied to compare three policy paradigms: (1) minimizing biological risk; (2) minimizing social risk, and (3) balancing risk approaches involving a zonation of forest land into areas where biological risk would be minimized through management interventions. This also includes areas where natural cycles of disturbance would be permitted to operate largely unmanaged, and the associated social risks addressed through institutional arrangements and reforms.
- Community vulnerability can be measured by developing a vulnerability framework; after the framework is developed, variables and indicators are identified and index scores assigned to each study community.
- FORREX Socio-economics Extension Working Group highlighted that relationships and participatory processes, economic development, and diversification as well as First Nations and research issues, were extremely important in planning for the socio-economic extension program and products. Partnering with the Beetle Action Coalitions should be an important focal point for program research and extension implementation.

Key Lessons Learned

- Current MPB management fails to adequately ensure that ecological values are protected.
- Socio-economic researchers must realize that communities want more than measurement of their strengths and weaknesses. Emphasis must be placed on development and implementation of measurable actions on the ground, so that identified issues and opportunities can be addressed.
- Evaluation of the optimum policy paradigms and socially acceptable balance would require scenario and value tradeoff analysis.
- Community vulnerability represents a high level of economic risk; for other communities, social and economic risk is exacerbated by institutional limitations.
- Community's perception of risk and biophysical assessments differ widely for communities anticipating future MPB outbreaks.
- The goal of managing a single resource in a sustainable manner may be difficult to achieve at the community level. Reductions in one form of capital (in this case MPB-affected areas) may need to be offset by increases in other forms capital, such as land in agriculture or investment in new industries (diversification of economies).
- Reductions of timber supply resulting from the MPB infestation will have serious negative consequences for all sectors of the economy.
- Increased tourism could partially or fully offset the impact on employment. This would further offset (to a lesser extent) the negative effects on monetary indicators. Increased traditional agricultural activity will minimally offset the impacts on employment and monetary indicators.
- Computable general equilibrium models constructed for each region provide a decision-support tool that can assist decision makers with mitigation planning for the anticipated reduction in timber supply caused by the MPB outbreak.
- Building frameworks to assess vulnerability relies on good social science research in the areas of climate change, community capacity, hazards management, and risk perception, as will as focus group meetings to bring together ideas and options.

Conclusion

Socio-economic, cultural, institutional, and biophysical studies related to the MPB have been numerous and interdisciplinary over the last decade. Although advancements and lessons learned have been gained from each of these studies, all indicate that there is room for research and development of programs and projects to circumvent the social, economic, cultural, and community-based complexities related to MPB impacts. Despite numerous financial, institutional, and jurisdictional efforts to mitigate the impacts of MPB, much remains to be done to provide communities with viable social and economic alternatives that coincide with various long-term strategic community or institutional visions. This is perhaps one of the more difficult obstacles overcome. Yet the notion that collective partnerships and linkages have reduced levels of community vulnerability and increased resiliency resonates among forest resource-dependent communities, natural resource-based industries, and First Nations groups.

Although numerous attempts have been made to understand the nature and complexities of the MPB, only a small proportion of useful information is potentially transferable. Even fewer of the "lessons learned" can be termed "appropriate or adoptable" for local communities. Resource-dependent communities rely on the strengths of individuals, groups, and organizations to build social, economic, human, and infrastructural capital. The nature and extent of the impacts of the MPB will determine the ability of communities to respond adequately to natural- or human-induced shocks and stresses. Work remains to be done in the areas of social, ecological, and cultural resilience, gender perspectives, community vulnerability, and the integration of holistic concepts of natural resources management from a First Nations perspective.

Despite numerous financial, institutional, and jurisdictional efforts to mitigate the impacts of MPB, much remains to be done to provide communities with viable social and economic alternatives that coincide with various long-term strategic community or institutional visions.

References

B.C. First Nations Pine Beetle Action Plan. 2006. First Nations Working Group report back to first nation leaders of mountain pine beetle impacted communities. Media release (April 11). URL: *http://www.fnforestrycouncil.ca/news_res/MediaReleaseApril1106.pdf*

British Columbia Ministry of Forests and Range. 2005. Mountain Pine Beetle Stewardship Research Strategy. Victoria, B.C. URL: *http://www.for.gov.bc.ca/hre/pubs/docs/MPBResearchStrategy.pdf*

United Nations Environment Program. 2008. Protected areas in today's world: Their value and benefits for the welfare of the planet. Secretariat of the Convention of Biodiversity, Montreal, Que. CBD Technical Series Number 36. URL: *http://www.cbd.int/doc/publications/cbd-ts-36-en.pdf*

Cariboo-Chilotin Beetle Action Coalition. 2007. 2004–2005 business plan. Williams Lake, B.C. URL: *http://beta.c-cbac.com/Documents/aboutus/CCBACBusiness%20PlanJuly27.pdf*

Intergovernmental Panel on Climate Change. 2001. Climate change 2001: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK. URL: *http://www.grida.no/publications/other/ipcc%5Ftar/?src=/climate/ipcc_tar/wg2/index.htm*

Omineca Beetle Action Coalition. 2007. OBAC Board approves proposed 2007 work plan. March Newsletter. URL: *http://www.ominecacoalition.ca/newsletter/OBACMar2007Newsletter.pdf*

Omineca Beetle Action Coalition. 2007. OBAC mineral exploration strategy. March Newsletter. URL: *http://www.ominecacoalition.ca/newsletter/OBACMar2007Newsletter.pdf*

Omineca Beetle Action Coalition. 2008. Minerals and mining sector strategy (2008). Prepared by DPRA for OBAC.

Orcherton, D.F., S. Boyd-Nöel, and J. Merrick. 2008. Beyond one-size-fits-all: Gender perspectives and the mountain pine beetle. LINK 10(2):24–26. URL: *http://www.forrex.org/publications/link/ISS52/vol10_no2_art17.pdf*

Parkins, J.R. 2008. The metagovernance of climate change: Institutional adaptation to the mountain pine beetle epidemic in British Columbia. Journal of Rural and Community Development 3(2):7–26.

Thematic Session Synthesis

"Beetle Beat": A First Nations' perspective on how the First Nations people have been affected by the mountain pine beetle

Gina Thomas[1]

Abstract

The First Nations Concurrent Session formed part of the Mountain Pine Beetle: From Lessons Learned to Community-Based Solutions conference, held June 10–11, 2008, at the University of Northern British Columbia, Prince George, B.C. This session highlighted a First Nations' perspective of the human dimension of the mountain pine beetle outbreak. Session panelists summarized First Nations' cultural and societal values as they have been affected by the outbreak. Topics covered included the impacts of the mountain pine beetle on First Nations' communities and non-timber forest products, and role of the First Nations Forestry Council.

KEYWORDS: *First Nations' communities, mountain pine beetle, non-timber forest products, wood medicines.*

Contact Information

1 Forest Research Extension Specialist, First Nations Forestry Council, 524 Island Highway, Campbell River, BC V9W 2C1. Email: extension@fnforestrycouncil.ca

Thomas, G. 2008. "Beetle Beat": A First Nations' perspective on how the First Nations people have been affected by the mountain pine beetle. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):60–64. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Introduction

The First Nations Concurrent Session formed part of the Mountain Pine Beetle: From Lessons Learned to Community-Based Solutions conference, held June 10–11, 2008, at the University of Northern British Columbia, Prince George, B.C. The session's host, Zandra Ross, and panel members Leonard Thomas, Albert Gerow, and Clara Jack, all originate from areas in British Columbia that have been severely affected by the mountain pine beetle (MPB). It has been said that the current MPB outbreak is the worst natural and economic disaster in British Columbia history. These panel members provided a First Nations' perspective on a forgotten aspect—the human dimension of the MPB outbreak. "For the 103 British Columbia First Nations territories affected by the mountain pine beetle infestation, this disaster threatens the long-term economic, stewardship, and socio-cultural aspects of First Nations' traditional ways of life" (Caverley 2008:150).

This paper provides a summary of First Nations' cultural and societal values as they have been affected by the MPB outbreak. Other conference presenters outlined additional critical areas of consideration when dealing with MPB-affected stands, such as biodiversity, socio-economics, and fibre opportunities and manufacturing (see, for example, synthesis papers by Lewis [page24], Orcherton [page 51], and Parisotto [page 71]).

Zandra began the "Beetle Beat" discussion with an introduction of her guests. Clara Jack, from the community of Nak'azdli Lake in Fort St. James, works for the Natural Resource Office with a background in non-timber forest resources. Every two weeks from May to October, she participates in teaching those interested in learning about plant identification and harvesting techniques. Clara referred to this as collecting their "wood medicine." Clara says, ". . . there is no more pine cambium . . . it is tainted with MPB and the blue mould . . . the sap is bubbly and the elders are not used to seeing that." Clara also stated that, ". . . the MPB used to only affect the bigger trees, now the MPB is affecting the smaller trees."

Zandra then introduced Albert Gerow from the Burns Lake First Nation. Albert told us that he, ". . . was born on a cold and windy morning back in March 1958 in the thriving metropolis of Burns Lake." His forestry career began at ". . . age seven cutting kindling for mom and dad's central heating unit which later progressed to larger pieces of kindling." He acquired forestry experience in the harvesting (falling and bucking) of trees and the use of larger harvesting equipment. He was a planer operator and an assistant manager with Babine Forest Products. This experience has given Al a good understanding of the process from the raw sawlog to the finished product. Al is now the Director of Operations with the First Nations Forestry Council (FNFC).

Session panelists provided a First Nations' perspective on the human dimension of the MPB outbreak.

Panelist Leonard Thomas began by acknowledging the First Nations' land that we were on for this conference. Leonard has been chief of the Nak'azdli people for 13 years. He has been a band manager, band counselor, and the economic development co-ordinator for the Nak'azdli and vice-president for the Carrier-Sekani Tribal Council. Leonard is currently the President of the FNFC. Leonard felt it was an easy transition going from politics into the forest sector. He felt it necessary to have the community get involved in the forest industry so Leonard helped his community develop a value-added mill. One of his main objectives was to ensure that the provincial government was involved with the MPB issue.

Impacts of the Mountain Pine Beetle on First Nations' Communities

Zandra began the session by asking Leonard, "Tell us, what are some of the impacts that the MPB is having on First Nations' communities"?

Leonard explained that First Nations people have been affected in several different ways—there were economics, health, cultural, and social issues. The value-added mill in Leonard's community employs 50 people and has been in operation for 13 years; however; it has taken them a long time to get to this point and now they feel they are taking a step back because of the downturn in the forest sector. The mill is currently operating 3 days a week due to the lack of fibre. Two other mills that this value-added mill depended on for fibre have recently shut down. This has resulted in the loss of 300 jobs in the forest sector. This community has had to look as far as Alberta for fibre to keep the mill running.

Community members are very worried about their futures if the industry does not rebound. Socially, this becomes a big issue because when times are tough and it becomes impossible to make the mortgage payments, First Nations people are extremely reluctant to leave the community. When times are tough, there are more social issues to contend with than normal. Lack of food can make individuals more aggressive . . . and lack of food could affect those with health problems such as diabetes, which has been continually increasing among the First Nations people of British Columbia. Leonard wants to let these employees know they are supported and valued. The MPB has affected the people culturally as well. The people were traditionally hunters and gatherers. Leonard told us that even the bears in his traditional territory are changing their migratory patterns.

In regards to government response to the MPB outbreak, Leonard had this to say.

> *$42 million was promised to us by Minister Coleman. To date we have not seen it all. The 2007 transfer agreement is different from the 2006 agreement and we had to fight with the federal government for money to protect our communities from the risk of fire and to date have only received the planning component. We figured we needed about $135 million and have not received a response. The lesson learned here is that the communities will apply for funding jointly the next time in hopes of a better response from the government. Some of that MPB money has been spent on airport upgrades like in Prince George. Many of the Forest and Range Agreements or Forest and Range Opportunities are opportunities that are no longer there. In July, the FNFC sent a team to China to look at potential markets internationally.*

In closing remarks, Leonard told us that there is a DVD about the mountain pine beetle by David Walkem and Linda Price, which can be acquired through the FNFC. He said the health and social climate of First Nations will be affected because many are still very dependent on the medicines in the forest. Educationally, they have recognized the need to train those looking for new skills (especially those in the forest sector). Math tends to have the greatest need for upgrading. In Leonard's words, "People have a lot of investment in their community. It is not easy to just move somewhere else when doom and gloom starts. We have a lot of challenges ahead of us."

Non-timber Forest Resources

Zandra asked Clara, "What are non-timber forest resources?"

Clara responded by telling us that non-timber forest resources are everything in the forest that is not made into milled lumber. She has spent many years working with traditional foods and medicines that she refers to as "wood medicines." These include ground-cover plants, shrubs, willows, and many types of trees. The people cannot collect the pine cambium anymore because the quality of the pitch has been affected by the blue mould the MPB leaves behind. Clara brought with her some samples of "wood medicines" she has collected. These samples included:

- Labrador tea – Clara is unsure how this plant will be affected in the future. It is currently found in swampy areas beneath the pine. The trees are dead and dying, the understorey now lacks shade, and there will be the potential for the soil to become more acidic with all the dead needles on the ground.
- Cranberry – The branches, leaves, and berries are harvested throughout the year.
- Kinnikinnick – A ground-cover plant; Clara is unsure how this plant will respond to the changing forest environment.
- Spruce pitch is prized by the youth as a type of chewing gum, but it is very useful with its antiviral/antibacterial properties.
- Subalpine fir (balsam) has been affected by the balsam beetle. The pitch has antiviral/antibacterial properties and is often used in the making of salves. The medicine from the balsam bark is used to combat colds. They use the bark in making teas and for smudging. Clara's grandfather used the bark to survive the flu epidemic in 1918.

Zandra also asked Clara, "What impacts have the MPB had on the plants you have harvested?"

Clara told us that they cannot find pitch or cambium anymore due to the MPB infestation. She has to go farther to look for the plants she needs and hopes to find some pitch in the area where her husband is currently working.

She thinks the soil may become more acidic and dry out, which would encourage different plants to grow. Clara and her people do not presently market their teas. They only harvest what they need. Last year, she missed out on collecting kinnikinnick because of an early snowfall. Currently, a community member is trying to market birch sap. It is not known what effect the dead pine will have on the remaining trees, such as birch, subalpine fir, and spruce.

First Nations Forestry Council

The last panel member to speak was Albert Gerow from the FNFC. Zandra asked Al, "Tell us more about the FNFC."

Al mentioned a presentation earlier in the day by Dan George (George 2008). Dan had described how the FNFC was born from the MPB working group through a cry for help from the communities affected by the MPB. Regional dialogue sessions with First Nations had presented a number of forestry-related issues. They wanted a body to represent First Nations forestry issues from corner to corner in British Columbia. The FNFC was established in 2006. A MPB Action Plan had been developed. Current FNFC board members include:

- President – Leonard Thomas, Nak'azdli First Nation
- Secretary-Treasurer – Chief Mike Retasket, Bonaparte Indian Band
- Chief Bill William – Squamish First Nation
- Chief David Walkem – Cook's Ferry Indian Band
- Dave Porter – Kaska Nation
- Harley Chingee – McLeod Lake Indian Band
- Chief Eric Joseph – Tsawataineuk First Nation

Office staff is presently at 3.5 employees.

Zandra's next question to Al was, "What is the FNFC doing to deal with these issues?"

Al told us that one of the greatest risks to communities affected by the MPB is fire. The FNFC had responded to help mitigate that fire risk by developing a fuel management toolkit along with the Ministry of Forests and Range, Indian and Northern Affairs Canada, and Natural Resources Canada. This fuel management toolkit was distributed to the 17 tribal councils as well as to the 103 First Nations affected by the MPB.[1] In addition, the Sappier Working Group secured personal use harvest rights (250 m^3) for a First Nations member in British Columbia. The FNFC is also helping communities affected by the MPB to develop management and action plans, and is providing support to apply for funding assistance. The FNFC works with government and other groups to promote forestry-related policy and programs.

The First Nations people must keep reminding the rest of the world that we need to change the way we think about our forests . . . in British Columbia, we must remember that forests have a very real human dimension as well.

Al's closing comments mentioned the China trade mission that Leonard had referred to earlier in the session. The objective is to look for markets for cedar, hemlock, and pressure-treated pine (for outdoor use). The FNFC is currently working on a British Columbia First Nations forest brand for wood marketed internationally. The First Nations database is just about finished. This will allow smaller companies to combine their fibre needs and to seek more marketing opportunities.

Closing Remarks

With the few minutes left in the First Nations session, Zandra asked the audience if they had any closing questions.

From the audience we heard "Is there a possibility in tourism jobs?" Leonard responded to this question. He said that community members have attempted to diversify by expanding into tourism. Small business operators soon discover the cost of insurance is too high to make a living at tourism-based jobs. We must continue to engage the Ministry of Tourism, Culture and the Arts on this issue.

I would like to thank our host Zandra Ross and our guest panel for participating in this session of "Beetle Beat." I hope that everyone was able to take something meaningful from this session and from the conference in general. We have a long way to go, but at least we know help is out there. The First Nations people must keep reminding the rest of the world that we need to change the way we think about our forests. "For example, when we use words like non-timber values, then everything in that forest is classified as a non-timber value. What is that saying? It is saying that the only thing that is of value in the forest is the

[1] To obtain a copy of the toolkit, contact the First Nations Forestry Council at: *admin@fnforestrycouncil.ca*

timber value, and the use for the lumber industry, and everything else is measured against that value" (Armstrong 2002:12). In British Columbia, we need to start remembering that the forests have a very real human dimension as well.

References

Armstrong, J. 2002. Natural ways of knowing: Positioning Indigenous Peoples' Knowledge in natural resource management. *In* Proceedings, Linking Indigenous Peoples' Knowledge and Western science in natural resource management. H. Michel and D. Gayton (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 11–15. URL: *http://www.forrex.org/publications/forrexseries/ss4.pdf*

Caverley, N. 2008. Understanding the human dimensions of the mountain pine beetle infestation: Lessons learned from the First Nations Mountain Pine Beetle Initiative. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. BC Journal of Ecosystems and Management 9(3):150–153. URL: *http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf*

George, D. 2008. Mountain pine beetle through a First Nations lens. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. BC Journal of Ecosystems and Management 9(3):15. URL: *http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf*

Thematic Session Synthesis

Silvicultural treatment and restoration options

R. Allan Powelson[1] and Kelly C. Osbourne[2]

Abstract

The catastrophic wildfires of 2003 and 2004 and the massive land base infested by the mountain pine beetle have resulted in an increasing area that is not sufficiently restocked with desirable tree species. The British Columbia Ministry of Forests and Range established the Forests For Tomorrow program to co-ordinate the silvicultural response within the affected forest management units. To effectively and efficiently respond to the challenges posed by large-scale catastrophic disturbances, the Forests For Tomorrow program utilizes a broad consultative and adaptive management approach.

KEYWORDS: *mountain pine beetle, operations, planning, silviculture.*

Contact Information

1 Regeneration Specialist, B.C. Ministry of Forests and Range, PO Box 9513 Stn Prov Govt, Victoria, BC V8W 9C2. Email: Allan.Powelson@gov.bc.ca

2 Forest Rehabilitation Planning Specialist, B.C. Ministry of Forests and Range, PO Box 9513 Stn Prov Govt, Victoria, BC V8W 9C2. Email: Kelly.Osbourne@gov.bc.ca

Powelson, R.A. and K.C. Osbourne . 2008. Silvicultural treatment and restoration options. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):65–70. URL: *http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf*

Introduction

The Forests for Tomorrow (FFT) program of the British Columbia Ministry of Forests and Range was established to address the growing not sufficiently restocked problem caused primarily by the catastrophic wildfires of 2003 and 2004 and the mountain pine beetle (MPB; *Dendroctonus ponderosae*) outbreak that is spreading throughout the interior of the province (Forests for Tomorrow 2007).

The FFT program is aimed at improving future timber supply and addressing risks to other forest values through the re-establishment of young forests on land that would otherwise remain under-productive in Timber Supply Area and Tree Farm License management units most affected by MPB. The program focusses on land that is primarily within the timber harvesting land base yet outside of forest industry obligations. It emphasizes surveying, site preparation, fertilization, and planting. Treatments are guided by strategic-level program planning, seed supply planning, silviculture strategies, and timber supply analyses. The program also funds the compensation of forest license holders whose legal reforestation obligations have been damaged by wildfire and some other natural disturbances under the *Forest and Range Practices Act* (*FRPA*) Section 108.

To successfully achieve government goals, FFT must move through consultative, strategic, and operational planning stages before carrying out a treatment. Several restoration options must also be considered before undertaking treatment activities. This paper, based on a presentation at the Mountain Pine Beetle: From Lessons Learned to Community-based Solutions conference held in Prince George, B.C., June 10–11, 2008, describes some of the planning steps and considerations that FFT employs in its treatment activities. Other conference presenters outlined additional critical areas of consideration when dealing with MPB-affected stands, such as stand dynamics, watersheds, and forest fire fuel management (see, for example, synthesis papers by Swift [page 17], Redding *et al*. [page 33], and Hawkes [page 77]).

> *To successfully achieve government goals, FFT must move through consultative, strategic, and operational planning stages before carrying out silvicultural treatments and must consider several restoration options.*

Operational Footprint

In 2008, approximately 13 million ha in British Columbia had been infested by MPB resulting in millions of dead lodgepole pine throughout the province. To calculate the areas where FFT can operate (i.e., the FFT footprint), the total area of dead lodgepole pine slated for salvage harvesting in the next 10 years must be subtracted from the total MPB-infested area. Salvage harvesting, in almost all cases, generates a legal reforestation obligation held either by the company that does the harvesting or the District Manager for the forest management unit in which the salvage occurs. This legal obligation ensures that the salvaged stands are reforested with healthy, ecologically suitable, commercially viable species.

Stands that have a sufficient living non-lodgepole pine component (> 30% of the stand's composition) are also subtracted from the total affected area as these stands represent a substantial contribution to the mid-term timber and habitat supply. Protection of these mixed-species stands from harvest ensures that the salvage program itself does not have a negative effect on the mid-term timber supply. When the areas slated for salvage and protection are removed from the total MPB-infested area, FFT uses a number of analysis tools to focus in on areas to survey that will most likely require reforestation (i.e., natural regeneration, access, and return on investment).

FFT footprint = Total area infested by MPB – Salvage Harvest – Mid-term Timber/Habitat

In 2008, the FFT operational footprint was estimated at approximately 400 000 ha to be treated over the next 20 years (300 000 ha of mature stands, 80 000 ha of immature stands, and 20 000 ha from fires).

Mountain Pine Beetle Rehabilitation Planning

After determining the FFT footprint, forest management units are prioritized for treatment based on the level of MPB impact on the mid-term and future timber supply; to do this, the percentage of the units' timber supply composed of lodgepole pine is compared to the amount of lodgepole pine affected by MPB. The prioritization process is co-ordinated with First Nations representatives and other stakeholders such as major forest licensees, communities, and the Ministry of Environment. The consultation process ensures that the desires of many stakeholders are recorded and taken into consideration during the initial planning stages. After the prioritization of forest management units is completed, selected areas within the unit's FFT footprint are scheduled for field survey.

Natural Regeneration

When field surveyors enter a selected stand, their first task is to assess and quantify the amount of living regeneration already present onsite. Although the amount of dead lodgepole pine in British Columbia is visually and numerically awe-inspiring, current research and operational surveys show that a large portion of these infested stands are not "dead" (Coates 2006; Hawkins and Rakochy 2007; Vyse *et al.* 2007). Considerable activity is occurring in both the research and operational worlds to gather information on the amount, species, and quality of natural regeneration in the understorey of lodgepole pine-dominated stands to determine appropriate silvicultural responses (Vyse *et al.* 2007).

Research and operational surveys show varying levels of understorey composition that will contribute to mid- and long-term timber and habitat supplies, and hydrological green-up (Table 1). Within the general trends by biogeoclimatic subzone, some variability does exist. Operational surveys show that, depending on the ecosystem, 1 out of 3 to 1 out of 9 ha are not adequately stocked with sufficient numbers of understorey stems of ecologically suitable species (Dow 2007a and 2007b; Weaver 2007). Research findings are confirming that considerable unexplained (at this time) variability exists (Coates 2006; Hawkins and Rakochy 2007; Vyse *et al.* 2007).

TABLE 1. Summary of the potential for understorey natural regeneration under MPB-affected stands by biogeoclimatic subzone (Coates 2006; Dow 2007a and 2007b; Hawkins and Rakochy 2007; Vyse *et al.* 2007; Weaver 2007)

High potential[a]	Moderate potential[b]	Low potential[c]
SBSmc3	SBSdw2d	IDFdk
SBSmk1	SBSdw3	SBSdk
SBSwk1	SBSmc2d	
MSdm3		
ESSFxc2		

[a] High rating when majority (+60%) of stands had stocking greater than 800 stems per hectare.

[b] Moderate rating when majority (50–60%) of stands had stocking greater than 800 stems per hectare.

[c] Low rating when minority (< 50%) of stands had stocking greater than 800 stems per hectare.

[d] Some variability existed in these biogeoclimatic subzones; some results show that these subzones may have high potential for sufficient levels of understorey regeneration.

When defining what is "adequately stocked with suitable species," the following silvicultural issues and risk factors must be considered:

- What forest health factors are present in all levels of the stand and how will these respond to the changing environment under a MPB-infested stand?
- How will the understorey and overstorey tree species present respond to the changing light environment in the infested stands?
- What species shifts are occurring? Is there a species shift to a lower commercial value or poor-performing species?
- Is the distribution and density of the remaining structure in both the understorey and overstorey sufficient to meet mid- and long-term supply demands?

Current research and operational experience is helping to clarify some of these questions.

Site Preparation

After reaching a decision to intervene in the infested stand, an appropriate treatment regime must be chosen. However, most current silvicultural treatments are based on harvest and wildfire approaches. How does the MPB disturbance regime alter the choice of treatment?

One of the first questions to ask is whether the overstorey should be left standing or knocked down. Research and operational experience show various responses are appropriate; currently, decisions are made according to considerations about natural regeneration and whether a commercial product can be salvaged from the MPB-infested stand.

Also considered are the large amounts of woody debris that result from mortality of the lodgepole pine overstorey. If the dead overstorey is knocked down, then is it sold, burnt, or scattered, and what are the public and ecological consequences of doing so? If left standing, then what impacts will the slow decay of the overstorey have and how will this affect fuel loading, understorey damage, worker safety, wildlife habitat, and biodiversity? Also, how does stand accessibility affect the decision to maintain or knock down the overstorey?

The following should be considered when determining the method of site preparation:

- Knock down or leave standing
- Disposal of woody debris (salvage harvest, roadside piling, fibre utilization, public opposition, real or perceived ecological impacts, etc.)
- Fuel loading and fire risk
- Worker safety
- Wildlife habitat and biodiversity
- Return on investment
- Community wildfire risk reduction
- Large-scale prescribed burns
- Access limitations
- Small mammal damage
- Foregoing potential future bio-energy opportunities

Planting

For areas deemed not have sufficient numbers of ecologically suited species, artificial reforestation may be considered. If this treatment option is selected, then appropriate reforestation species must be chosen. These must be ecologically suitable and, if the area contributes to the timber harvesting land base, commercially valuable. Most decisions regarding ecologically suitable commercially valuable species are based on previous species decision research (B.C. Ministry of Forests 2000). Decisions about acceptable species, however, must be moderated by future climate considerations; the stand development pathways these reforested species will follow are largely unknown in the face of climate change.

The species choice also needs to consider species' responses to micro-environments altered by decaying MPB-infested stands. Our current understanding is based on older silvicultural system trials that have been extrapolated to MPB-affected stands. This information may not adequately encompass the structural and temporal differences in these environments. Current modelling and fieldwork studies have provided some insights, but further research is needed (Coates and Hall 2005; Hawkins and Rakochy 2007; Nigh 2007; Vyse *et al.* 2007). In addition, current assumptions about appropriate reforestation densities are also based on responses under harvesting scenarios, and it is not known whether these assumptions adequately address the growth and survival under a MPB-affected stand.

Fertilization

Our response to the damage caused by MPB must incorporate a range of tools. Growth of established trees, either those not affected by MPB or those established in MPB-affected stands, can be improved to help mitigate the anticipated mid-term timber supply shortfalls resulting from the MPB infestation. Although newly planted trees can be helped with at-time-of-planting fertilizers, research also shows that fertilizer applications can significantly increase tree growth in areas outside the timber harvesting land base occupied by very high density, growth-suppressed pine not infested by MPB and in areas adequately stocked by other non-pine species (Blevins *et al.* 2005; Brockley 2007). Fertilization treatment can increase growth, helping to provide timber in the mid-term. The Ministry of Forests and Range currently fertilizes substantial areas of non-pine stands throughout British Columbia with this goal in mind (approximately 25 000 ha in 2008). The fertilization of suppressed pine is not yet operational, but research results show favourable responses (Blevins *et al.* 2005).

Stand Tending

Juvenile spacing can also help to offset mid-term timber supply shortfalls by increasing the rate at which stands achieve the minimum harvestable size (Blevins *et al.* 2005); however, spacing incurs higher per hectare costs. Therefore, little operational work is currently under way because it is not known whether this treatment provides a positive return on investment. Future climate change, and associated variation in the occurrence of pathogens and wildfire, poses a long-term risk to these stands and the potential for loss of this investment.

Vegetation Management

After a stand is re-established on a MPB-affected site, it is essential to have a monitoring program in place to ensure that the seedlings maintain the desired growth and survival rate. As with tree species' decisions, our understanding of non-crop vegetation response is based on harvesting scenarios. How non-crop vegetation responds to the changing environment under a non-salvaged MPB-affected stand is largely unknown. To date, the response of competing understorey vegetation to micro-environmental changes related to the MPB infestation has not been extensively studied.

Information Integration

Operationally conducted surveys must be integrated with forest and resource inventory updates to construct an accurate picture of the forest. In this way, future timber supply projections can reflect the actual state of the forest resource. However, using current survey systems in MPB-affected stands may be inappropriate. Martin (2007) is developing some procedures to quantify the state of the timber resource following salvaging operations that may be further modified for use in MPB-affected stands.

Moving Forward

The Forests for Tomorrow program uses an adaptive management framework to integrate the results of silvicultural trials and formal research projects directly into its treatment practices. The program is also developing a landscape-level risk analysis process, initiating the co-ordination of all levels of existing plans, and investigating large-scale integrated treatments as the program moves away from a stand-level focus toward a landscape-level focus.

The Forests for Tomorrow program uses an adaptive management framework to integrate the results of silvicultural trials and formal research projects directly into its treatment practices.

Acknowledgements

The authors would like to acknowledge Guy Newsome, Chris Hawkins, Teresa Newsome, Gord Dow, Ljiljana Knezevic, Alanya Smith, Gord Nigh, Graham Hawkins, and Kathie Swift for providing input into this paper. We would also like to acknowledge Southern Interior and Northern Interior forest region staff, forest district staff, Recipient Agreement Holders, MPB-affected communities, the First Nations Mountain Pine Beetle Initiative, the First Nations Forestry Council, and many others for ensuring the continues success of the MPB Rehabilitation Program.

References

Blevins, D.P., C.E. Prescott, H.L. Allen, and T. Newsome. 2005. The effects of nutrition and density on growth, foliage biomass, and growth efficiency of high-density fire-origin lodgepole pine in central British Columbia. Canadian Journal of Forest Research 35:2851–2859.

British Columbia Ministry of Forests. 2000. Establishment to free growing guidebook. B.C. Ministry of Forests, Victoria, B.C.

Brockley, R.P. 2007. Effects of 12 years of repeated fertilization on the foliar nutrition and growth of young lodgepole pine in the central interior of British Columbia. Canadian Journal of Forest Research 37:2115–2129.

Coates, D. 2006. Silviculture and the mountain pine beetle: What to do [presentation]. B.C. Ministry of Forests and Range, Victoria, B.C.

Coates, D. and E. Hall. 2005. Implications of alternate silvicultural strategies in mountain pine beetle damaged stands. Bulkley Valley Centre for Natural Resources Research and Management, Smithers, B.C. Technical Report Y051161.

Dow, G. 2007a. Mountain pine beetle in juvenile spaced immature stands: A summary of results of preliminary reconnaissance surveys – Prince George District. B.C. Ministry of Forests and Range, Prince George, B.C.

______. 2007b. Mountain pine beetle in juvenile spaced immature stands: A summary of results of preliminary reconnaissance surveys – Vanderhoof District. B.C. Ministry of Forests and Range, Prince George, B.C.

Forests for Tomorrow. 2007. Program management plan. B.C. Ministry of Forests and Range, Victoria, B.C. URL: *http://forestsfortomorrow.ca/ProgramManagement/ProgramManagementPlan/Documents/FFT_Mgt_Plan_2007.pdf*

Hawkins, C. and P. Rakochy. 2007. Stand-level effects of the mountain pine beetle outbreak in the central British Columbia interior. Canadian Forest Service, Victoria, B.C. Working Paper 2007-06.

Martin, P. 2007. Partial-cut resource stewardship monitoring protocol. Forest Resource Evaluation Program. B.C. Ministry of Forests and Range, Victoria, B.C. Unpublished draft.

Nigh, G. 2008. Density and distribution of advance regeneration in the MS biogeoclimatic zone in relation to site moisture and overstory density [presentation].

Growth and Value Conference, February 6–7, 2008. Bulkley Valley Centre for Natural Resources Research and Management, Smithers, B.C.

Vyse, A., C. Ferguson, J. Roach, and B. Zimonick. 2007. Regeneration beneath lodgepole pine dominated stands attacked or threatened by mountain pine beetle in the Kamloops Timber Supply Area. Unpublished draft.

Weaver, D. 2007. Executive summary and interpretation: Data analysis selected 2006 FFT silviculture surveys – Immature MPB Pl Stands. B.C. Ministry of Forests and Range, Nadina Forest District, Smithers, B.C.

Thematic Session Synthesis

Fibre opportunities and manufacturing

Robert Parisotto[1]

Abstract

By 2015, an estimated 76% of the merchantable pine in the British Columbia interior will have died as a result of the mountain pine beetle (MPB) outbreak. Since pine makes up about 40% of the Interior's forests, the outbreak has tremendous consequences for biodiversity, forest health, and the communities and businesses that rely on these forests for their livelihoods. As the provincial agency responsible for developing and diversifying markets for British Columbia wood products, Forestry Innovation Investment (FII) was given accountability for the wood products research and development component of the federal-provincial emergency response implementation strategy, and the related $5.85 million in spending over 3 years. The Fibre Opportunities and Manufacturing Concurrent Session, which formed part of the Mountain Pine Beetle: From Lessons Learned to Community-based Solutions conference, held June 10–11, 2008, at the University of Northern British Columbia, allowed presenters to share some key research work carried out over the last 3 years. A brief overview of the FII MPB program was presented, highlighting the number of research projects carried out within the MPB program activity area. John Taylor of FPInnovations–Forintek Division then gave a presentation focussing on technological advances in processing MPB fibre in a primary lumber manufacturing facility. Azzeddine Oudjehane, representing the University of British Columbia's Department of Wood Science, outlined work done in developing new engineered and composite wood products utilizing MPB-attacked fibre.

KEYWORDS: *mountain pine beetle, shelf-life, technology, wood products research.*

Contact Information

1 Director, Product Development and Technical Research, Forestry Innovation Investment, Suite 1200, 1130 West Pender Street, Vancouver, BC V6E 4A4. Email: robert.parisotto@bcfii.ca

Parisotto, R. 2008. Fibre opportunities and manufacturing. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):71–76. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Background

The mountain pine beetle (MPB) outbreak is the largest infestation of pine beetles in the recorded history of North America. By 2015, it is estimated that 76% of the merchantable pine in the British Columbia interior will have died as a result of the outbreak. Since pine makes up about 40% of the Interior's forests, the outbreak has tremendous consequences for biodiversity, forest health, and the communities and businesses that rely on these forests for their livelihoods.

In the winter of 2005, the provincial government called for a British Columbia–Canada partnership to deal with the MPB outbreak. The government was in consultations with local communities, forest companies, First Nations, and other stakeholders on its Mountain Pine Beetle Action Plan 2005–2010 (Province of British Columbia 2005a) and was looking for federal support to deal with the situation. The federal government responded with a commitment to work with the province in developing a co-ordinated response and a contribution of $100 million over 3 years. Subsequent discussions led to the release of the Mountain Pine Beetle Emergency Response–Canada-B.C. Implementation Strategy (Province of British Columbia 2005b) in the fall of 2005 and the updating of the action plan to cover 2006–2011 (Province of British Columbia 2006).

The action plan is the cornerstone of the provincial government's response to the MPB crisis. In the plan, the government committed to actions that will mitigate MPB impacts on forest values, communities, and the provincial economy in the short term, and ensure sustainability in the long term. It provides a high-level framework to direct provincial ministries and Crown agencies, and to assist co-ordination between all levels of government, First Nations, industries, and stakeholders. With the federal government's priorities in mind, the original plan outlined the allocation of the $100 million.

Co-ordination of the plan was placed with the MPB Emergency Response team in the Ministry of Forests and Range. Activities, and accountability for the related budget, were seconded to more than 10 ministries or government agencies, based on expertise and mandate. Full details on the federal-provincial strategy and the provincial action plan, including progress reports, are posted to the MPB website at: *http://www.for.gov.bc.ca/hfp/mountain_pine_beetle*

Because pine makes up about 40% of the Interior's forests, the mountain pine beetle outbreak has tremendous consequences for biodiversity, forest health, and the communities and businesses that rely on these forests for their livelihoods.

Forestry Innovation Investment's Role in the Mountain Pine Beetle Strategy

As the provincial agency responsible for developing and diversifying markets for British Columbia wood products, Forestry Innovation Investment (FII) was given accountability for the wood products research and development component of the strategy, and the related $5.85 million in spending over 3 years.[1]

The wood products research objective was to recover the greatest value from dead timber before it burns or decays, while respecting other forest values. Specifically, the program was mandated to cover:

- Product development and technical research
- Product and market opportunity analysis
- Market access and phytosanitary issues
- International customer communications

Funding was targeted as follows:

• Fiscal 2005/06:	$1.35 million
• Fiscal 2006/07:	$2.25 million
• Fiscal 2007/08:	$2.25 million
• Total:	$5.85 million

The rationale for the wood products research was the recognized need to establish and maintain viable markets for the large volume of dry, blue-stained wood resulting from the MPB infestation. The plan was to solve immediate manufacturing problems as quickly as possible, to improve the economic viability of the dead dry wood, and to develop new products and markets for the material. Marketing support was seen as necessary throughout the full harvesting period.

[1] For more information about Forestry Innovation Investment, go to: *http://www.bcfii.ca/industry_resources/mountain_pine_beetle_info.htm*

To establish profitability and maximize value, product development was considered particularly important in the early phases of the program. As a result, the funding was designed to bring about intensified, collaborative efforts between various agencies, universities, institutes, and industry for:

- Supporting studies to determine the shelf-life of the dead trees
- Investing in research to examine the impacts of increasingly dry pine logs coming into the mills
- Identifying and qualifying other markets for blue-stained timber and products
- Investing in broad product research to develop new composite products from blue-stained timber
- Investing in research to determine the impacts on the pulp and paper industry of a changing chip/pulp resource
- Investing in strategies to develop products for niche markets
- Completing market research to monitor and report on major competitors in the key markets of the United States and Japan
- Conducting opportunity analyses in new markets
- Developing and delivering a communication program for offshore markets led by the British Columbia industry

Fibre Opportunities and Manufacturing Concurrent Session

The Fibre Opportunities and Manufacturing Concurrent Session formed part of the Mountain Pine Beetle: From Lessons Learned to Community-based Solutions conference, held June 10–11, 2008, at the University of Northern British Columbia, Prince George, B.C. This session allowed presenters to share some key research work carried out over the last 3 years. Presenters at other concurrent sessions outlined additional critical areas of consideration when dealing with MPB-affected stands, such as First Nations' cultural and societal values, and socio-economics (see, for example, synthesis papers by Thomas [page 60] and Orcherton [page 51]).

Given the broad scope of the research conducted and the 1-hour time frame available, the presentation material focussed on:

- Research conducted to assist lumber manufacturers in processing MPB-attacked fibre
- Product development opportunities that have been undertaken using MPB-attacked fibre

I started the session with a brief overview of the FII MPB program, highlighting the number of research projects carried out within the MPB program activity area. John Taylor of FPInnovations–Forintek Division then gave a presentation focussing on technological advances in processing MPB fibre in a primary lumber manufacturing facility. Azzeddine Oudjehane, representing the University of British Columbia's Department of Wood Science, finished the 1-hour session by outlining work done in developing new engineered and composite wood products utilizing MPB-attacked fibre.

The dedicated funding stream that FII received as part of the $100 million initial federal government funding came to an end in 2007–2008. In May 2008, FII produced a summary report (Forestry Innovation Investment 2008) that outlined accomplishments from 2005 to 2008. During the session, I highlighted key project work funded by FII over this time frame. Highlights included:

- 50 research projects completed over the 3-year period
  - 10 projects: Fibre quality focus
  - 14 projects: Manufacturing processes focus
  - 20 projects: Product development focus
  - 6 projects: Market development focus
- Three mill studies were also completed that compared lumber recovery and value yields when processing green S-P-F logs and grey-stage (5+ years time since death) MPB-attacked logs. The studies were conducted in high-speed dimension lumber mills and provided statistically sound data to assist industry and government in the assessment of economic shelf-life for MPB-attacked logs.

Taylor's presentation centred on technological advances specific to the primary lumber manufacturing sector. The three major problems that manufacturers face when processing MPB-attacked fibre are checks (cracks) in the logs, low moisture content, and increased abrasiveness.

Taylor discussed:

- Check detection and mitigation advances
- Sawing studies and improvements specific to MPB-attacked fibre
- Kiln-drying issues and opportunities

The check detection portion highlighted technological advances in vision- and x-ray-based solutions, value optimization, and current technologies employed. In 2005–2006, Forintek undertook a study to capture true shape and surface defects in a large sample of MPB-attacked log stems. To facilitate data collection, a machine vision system was developed, whereby cameras and LED lights captured digital pictures of log ends and sides. Image-processing software then identified and measured the defects from the digital pictures. More recently, Forintek has investigated the ability of x-ray-based scanning systems to detect and characterize checks. The objective of this work was to determine the minimum technical requirements for a practical online scanning system and to determine the possible increase in lumber recovery. This work is ongoing. Forintek has also been using "Optitek," their in-house sawmill modelling software, to better understand how check characteristics (depth, length, orientation, frequency) affect lumber recovery and value. Taylor illustrated the advances made and currently used by industry, showing log-scan snapshots from Porter Engineering. This technology allows the checks to be scanned (leading end of log, trailing end of log, and side of log); then, the log is oriented at the primary log breakdown (canter) infeed to optimize the value recovery from the log.

Taylor then moved into a discussion of sawing technology improvements that address the unique characteristics in processing MPB-attacked fibre. Research in the following saw technology areas was outlined:

- Performance of different circular saw designs (number of teeth in circular saw)
- Increased processing speeds
- Tip wear for different materials and tip shape
- Maintenance (alignment)
- Thin kerf saws

Forintek undertook studies on saws with 30-, 40-, 50-, and 60-tooth saw designs. All saws were 17" (43 cm) in diameter with a plate thickness of 0.075" (2 mm). The research showed that:

- increasing the feed speeds made no significant difference to the mean or standard deviation of 30- and 40-tooth saws; and
- as the number of saw teeth and feed speeds increased, saw performance deteriorated.

Tip wear research was conducted on saws with the following tip materials: Carbide, Stellite™, and Cermet A, B. Cermet A, B material proved best in wear, when comparing saw tooth radius before and after testing.

Key conclusions presented on saw performance in processing MPB-attacked fibre were as follows:

- Two identical sets of saws can perform significantly differently. More research is required to understand why this may be the case.
- Mean deflection is a more sensitive measurement of saw performance than deviation.
- Fewer teeth per saw provided better cutting performance, although tooth breakage can be a limiting factor.
- Reducing side clearance can allow for significant kerf reduction without increasing deviation.
- Misalignment causes more problems with wedging than deviation.

The issues faced and technological advances made when kiln-drying MPB-attacked fibre was the final area discussed. Lumber milled from MPB-attacked wood exhibits a lower initial moisture content, which creates the potential for over-drying, given Canadian Food Inspection Agency (CFIA) Heat Treatment (HT) requirements. Minimum kiln residence times of 12 hours are required. The agency requirements are for lumber to reach a core temperature of 56°C for a minimum of 30 minutes. Longer than necessary kiln residence times can contribute to:

- over-drying and subsequent additional degrade of lumber;
- excessive energy consumption; and
- loss in productivity.

All can contribute to significant dollar losses for the mill. Taylor provided results of a Forintek member survey, where information was obtained on mills with the ability to moisture-sort before drying, and the level of technology mills employed to control humidity levels in their kiln-drying process. The CFIA kiln-drying options available to the mill depended on the kiln-drying technology available. Mills equipped with low-pressure steam or cold-water spray benefited from the CFIA drying schedule they were able to utilize. Estimated over-drying and the resulting degrade was significantly less in mills with low-pressure steam or cold-water spray technology in their kilns than in those without this capability. Results show that limited control of relative humidity in the kiln-drying process, coupled with "longer" drying schedules leads to over-drying and subsequent lumber degrade. As a result, Forintek is continuing with research to evaluate the effect of low-pressure steam or cold-water spray on product quality and phytosanitary requirements. Taylor ended his discussion on kiln-drying MPB-attacked fibre by noting that the opportunity due to modified or shorter kiln-drying schedules could lead to a potential 30% reduction in energy consumption.

Oudjehane's presentation focussed on development of new engineered and composite wood product opportunities for MPB-attacked fibre. He started by describing MPB-attacked pine as a new product material and looking beyond what can be done with this fibre once we pass economic shelf-life as a sawlog. What can be done with the available resource? Options include value-added wood products, engineered and composite wood products, and biofuel.

Oudjehane then discussed product options available given various forms of the raw material input (from lumber to veneer to strands to particle fibre to fine powder). Structural products can be produced from the lumber, veneer, and strand raw material inputs, and non-structural products can be produced from particle or powder raw material inputs. Examples of structural products include glulam, cross-laminated timber panels, and oriented strand lumber. The processing of MPB fibre into engineered or wood composite products was described as a three-step process:

1. processing the logs into the necessary input form (i.e., veneer or strand);
2. blending the input fibre with a bonding agent; and
3. pressing into an end product.

As with any new product undertaking, challenges and opportunities present themselves. New processing technologies and new markets are critical components for the launch of a product. Oudjehane outlined past and present new product initiatives under way, including:

- Development of thick MPB strand composites
- Development of thick MPB wood plates
- Development of MPB wood cement
- Development of MPB wood plastics
- Development of cross-laminated veneer timber and veneer lumber

Past and current process development initiatives include:

- Innovative methods for moisture conditioning MPB logs for OSB production
- Pre-heating technology for processing MPB strand-based engineered wood products

The overall UBC research objectives for the MPB new product opportunities are twofold: understand issues related to properties, performance, and manufacturing; and technical feasibility assessment of new products.

Lower moisture content and log checking have created unique issues in the manufacture of veneer for the plywood industry, and an ever-increasing volume of blue-stained chips in the pulp sector has created issues related to bleaching and maintaining brightness quality.

Oudjehane discussed the opportunity or rationale for each of the new product initiatives under way. As an example, thick-strand oriented stand lumber has applications as floor beams and roof headers. The MPB wood cement allows for efficient use of fines and particles, satisfies a demand for fire-resistant materials, and has a wide range of end-use applications including sidings and non-structural interior panels or counter tops. Important achievements include the development of prototype products (thick-strand composite panels, full-size laminated plates, wood cement products, and wood plastic pellets). Performance testing and analysis have also been a key activity in the development of these products. The Wood Sciences Department has undertaken a number of strength and bending tests on the prototype products to ensure these products can withstand the necessary regulatory requirements and consumer expectations in the market place.

The presentation concluded with a description of the innovative pre-heating technology for processing thick-strand composite products.

Conclusion

The time available for this concurrent session allowed discussion of only a few activities related to wood product research and development. Research related to the existing "primary" manufacturing sector has also been carried out to address MPB fibre-related issues in the plywood and pulp sectors. Lower moisture content and log checking have created unique issues in the manufacture of veneer for the plywood industry, and an ever-increasing volume of blue-stained chips in the pulp sector has created issues related to bleaching and maintaining brightness quality. A significant amount of funding has also been directed at the "secondary" manufacturing sector, looking at value-added opportunities for MPB-attacked fibre.

References

Forestry Innovation Investment. 2008. Three-year status report: Mountain pine beetle program. URL: *http://www.bcfii.ca/industry_resources/pdf/MPB_Report_Final.pdf*

Oudjehane, A. 2008. Opportunities for MPB fibre: Engineered and composite wood products. Presentation to the Fibre Opportunities and Manufacturing Concurrent Session, Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference, June 10–11, 2008, Prince George, B.C. For more information go to: *http://www.forestry.ubc.ca/team*

Province of British Columbia. 2005a. British Columbia's mountain pine beetle action plan: 2005–2010. Victoria, B.C. URL: *http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/actionplan/2005/contents.htm*

________. 2005b. Mountain pine beetle emergency response: Canada-B.C. implementation strategy. Victoria, B.C. URL: *http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/MPB-Implement-Strat-Sept05.pdf*

________. 2006. Mountain pine beetle action plan, 2006–2011: Sustainable forests, sustainable communities. Victoria, B.C. URL: *http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/actionplan/2006/Beetle_Action_Plan.pdf*

Taylor, J. 2008. Technological advances: Current primary industry focus. Presentation to the Fibre Opportunities and Manufacturing Concurrent Session, Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference, June 10–11, 2008, Prince George, B.C. For more information, go to: *http://www.forintek.ca/public/Eng/EE0-default_eng/EE0-default_eng.html*

Thematic Session Synthesis

Effects of the mountain pine beetle on fuels and fire behaviour

Brad Hawkes[1]

Abstract

Tree mortality induced by the mountain pine beetle (MPB) results in important changes to fuel characteristics, fire environment, and subsequent fire behaviour. The Fuel Loading and Fire Behaviour Concurrent Session formed part of the Mountain Pine Beetle: From Lessons Learned to Community-based Solutions conference, held June 10–11, 2008, at the University of Northern British Columbia. This session examined our knowledge of the immediate and long-term effects of MPB on fuel characteristics, fire environment, and behaviour; the changes in annual burn rate following past MPB outbreaks; experimental burning projects; the use of fuelbreaks in stands affected by MPB; the B.C. Ministry of Forests and Range's fuel management program; and impacts of MPB on First Nations.

KEYWORDS: *fire behaviour, fire environment, First Nations' communities, fuel characteristics, fuel loading, mountain pine beetle.*

Contact Information

1 Fire Research Officer, Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, 506 West Burnside Road, Victoria, BC V8Z 1M5. Email: BHawkes@pfc.cfs.nrcan.gc.ca

Hawkes, B. 2008. Effects of the mountain pine beetle on fuels and fire behaviour. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):77–83. URL: *http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf*

Introduction

The Fuel Loading and Fire Behaviour Concurrent Session, which formed part of the Mountain Pine Beetle: From Lessons Learned to Community-based Solutions conference, held June 10–11, 2008, at the University of Northern British Columbia, examined our knowledge in the following areas:

- Immediate and long-term effects of mountain pine beetle (MPB) on fuel characteristics, fire environment, and behaviour
- Changes in annual burn rate following past MPB outbreaks
- Experimental burning projects
- Fuelbreaks in stands affected by MPB
- B.C. Ministry of Forests and Range fuel management program
- Impacts of MPB on First Nations

The thematic session presentation summarized here was based on two talks given on March 27, 2008, as part of a "National Conversation on Forest Fire Management" series produced by the Canadian Interagency Forest Fire Centre, Science and Technology Working Group (Duffy and Harvey 2008; Lavoie and Taylor 2008). This session was also based two short articles published in the July/August, 2008, issue of the *BC Forestry Professional Magazine* that discussed mountain pine beetle impacts on fuel loads and management and fire behaviour (Duffy 2008; Lavoie and Hawkes 2008). Other conference presenters outlined additional critical areas of consideration when dealing with MPB-affected stands, such as stand dynamics, watersheds, and First Nations cultural and social values (see, for example, synthesis papers by Swift [page 17], Redding *et al.* [page 33], and Thomas [page 60]).

Immediate and Long-term Effects of the Mountain Pine Beetle on Fuel Characteristics, Fire Environment, and Behaviour

Tree mortality induced by the MPB results in important changes to fuel characteristics, fire environment, and subsequent fire behaviour. For example, increases in the proportion of dead fine and coarse woody fuels in the tree canopy will, over time, increase the surface woody fuel load as MPB-killed trees fall over. Fire environment changes include those to microclimate and fuel moisture content. Fire behaviour is influenced by fuel, weather, and topography. Modifications to components of the fire environment by MPB have the potential to affect the way in which fire ignites, develops, and spreads. Any resulting fire behaviour will most likely vary as a function of the degree of change in the fuel characteristics and environment. In turn, these changes vary depending on MPB attack intensity, initial stands conditions (e.g., stand density, tree crown base height, and surface fuel load), and years since MPB attack.

Tree mortality induced by the MPB results in important changes to fuel characteristics, fire environment, and subsequent fire behaviour.

After MPB attack, stands go through three major stages: red attack (1–3 years after infestation), grey attack (3–10 years after infestation), and snag attrition (10–20 years after infestation). In the red stage, needles turn red in the year after attack, have reduced moisture content (down to 5–15% when conditions are conducive to fire), and respond quickly to changes in atmospheric conditions. Needle moisture content is a variable considered in crown fire initiation and spread. Low needle moisture content increases the potential for crown fires.

In the grey stage, most of the needles have fallen to the forest floor, which decreases the fine fuels in the tree crowns. The lack of needles allows solar radiation to penetrate the tree canopy to the forest floor; as a result, in-stand wind speeds increase and interception of rainfall by the trees decreases. Increased solar radiation and soil moisture content might change the understorey species composition and increase their growth rates. Although the effects of MPB on microclimate and fuel moisture have not been examined directly, Whitehead *et al.* (2008) observed these changes following spacing. A mature stand of lodgepole pine in southeastern British Columbia had approximately half of the basal area removed by thinning from below to a uniform 4-m intertree spacing, which resulted in decreased canopy interception of rainfall and increased within-stand solar radiation, wind speed, and near-surface air temperature. Moisture content of both needle litter and fuel moisture sticks were most different in thinned and unthinned stands following rainfall, but these differences decreased rapidly as fuels dried (Figure 1). Under moderate fire danger conditions, between-treatment differences were very small and not practically significant.

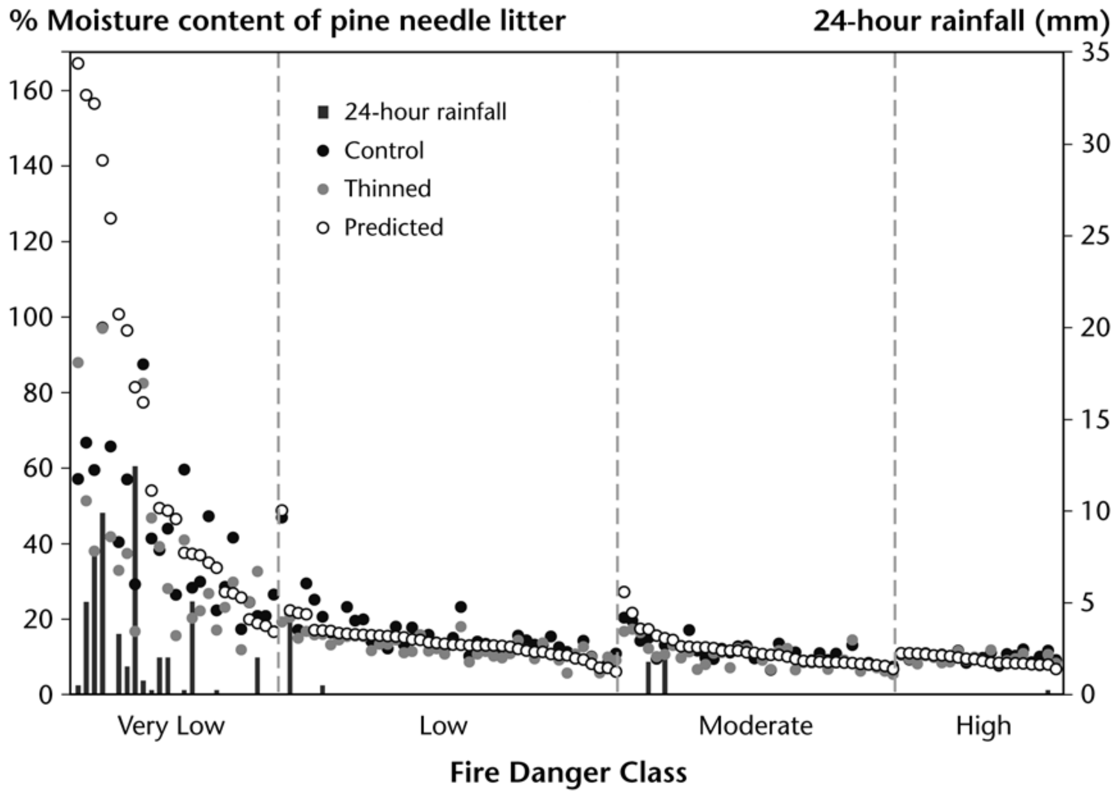

FIGURE 1. Predicted and actual moisture content of needle litter, plotted from wettest to driest predicted value within fire danger class (24-hour rainfall is shown as vertical bars; Whitehead *et al.* 2008).

In the snag-attrition stage, MPB-killed trees start to fall down and become surface fine and coarse woody fuels. The increased fuel load on the forest floor has the potential to increase surface fire intensity, the probability of crown involvement in remaining live trees, as well as fire severity and other fire effects. Surface fine and coarse woody fuels are already present before MPB-killed pine fall down because of trees killed by the previous stand initiation disturbance and natural thinning of the stand as it grows.

Hawkes *et al.* 2005 examined fuel loads at a number of locations in British Columbia and southern Alberta in current and past MPB outbreaks and demonstrated the use of Prognosis^{BC} (the British Columbia variant of the Forest Vegetation Simulator) and the northern Idaho variant of the Fire and Fuels Extension (FFE) to project changes in stand structure, fuel loading, snag density, and potential fire behaviour following MPB outbreaks. Because of the differing disturbance histories and ecological conditions, substantial variation occurs in the amount of fine and coarse surface woody fuels in pine stands before MPB attack. This is an important consideration when trying to determine future fuel loads. For example, the surface woody fuel load estimated for Manning Provincial Park in 2002 before snag attrition was similar to that in Waterton Lakes National Park after 52% of snags fell down. In addition, a study at Tetachuck Lake was modelled for future fine and coarse woody loads. The FFE model predicted that from 2002 to 2031 fine fuel loads would increase from 5.6 to 14 t/ha and coarse fuel loads would increase from 24 to 70 t/ha (Table 1).

Changes in Annual Burn Rate Following Past Mountain Pine Beetle Outbreaks

Mountain pine beetle outbreaks have occurred in British Columbia many times in the past, and have been mapped since the 1930s. Historic fire records and MPB outbreak maps were overlaid to determine whether any changes in the occurrence or area burned

TABLE 1. Fine and coarse woody fuel loading and percent of overstorey trees that have fallen over by study area (Hawkes *et al.* 2004)

	Years since MPB attack	Fine (≤ 7 cm) woody fuel load (t/ha)	Coarse (> 7 cm) woody fuel load (t/ha)	% overstorey trees that have fallen
Current MPB outbreak				
Manning Provincial Park	0	4.3	45	No fall down
Tetachuk Lake	4	5.6	24	No fall down
Tetachuk Lake stands[a]	33	14	70	
Past MPB outbreaks				
Kootenay National Park	10	3.5	44	24
Chilcotin Plateau	16	5.3	28	52
Waterton Lakes National Park	19	6.8	42	52

[a] Using Prognosis[BC] and U.S. Fire and Fuel Extension (predicted for 2031).

TABLE 2. Fire occurrence and burned area in mountain pine beetle outbreaks in British Columbia (1960–2001) (Taylor *et al.* 2005)

MPB outbreak area (ha)	No. fires[a] > 20 ha	Area burned[a] (ha)	Area burned (%)	Annual burn rate (%)	Mean fire size (ha)
4 820 533	276	33 557	0.70	0.017	122

[a] Within MPB outbreak area.

by fire were evident in past MPB outbreaks. For the period 1960–2001, Table 2 shows a number of statistics, including the total MPB-affected area, the number of fires greater than 20 ha, total area burnt, portion of MPB-affected area burnt, annual burn rate, and mean fire size. In addition, the waiting time distributions of the normalized burn rate suggest that MPB temporal patterns were significant. For example, peaks in burnt MPB-affected areas are evident during the red-needle and snag-attrition stage (Figure 2).

Although the theoretical basis for MPB and fire interaction seems sound in relation to the changes in the fuel complex, empirical evidence is less clear based on past fire and insect occurrence. This is mainly due to the relatively short period of observation and fire suppression effectiveness. Only a small number of escape fires occurred in MPB outbreak areas and fire sizes are confounded by fire suppression. The mean annual burn rate following MPB outbreak is less than 0.02% (Table 2). See Taylor *et al.* (2005) for more information on the interaction of fire and MPB and other insects in British Columbia.

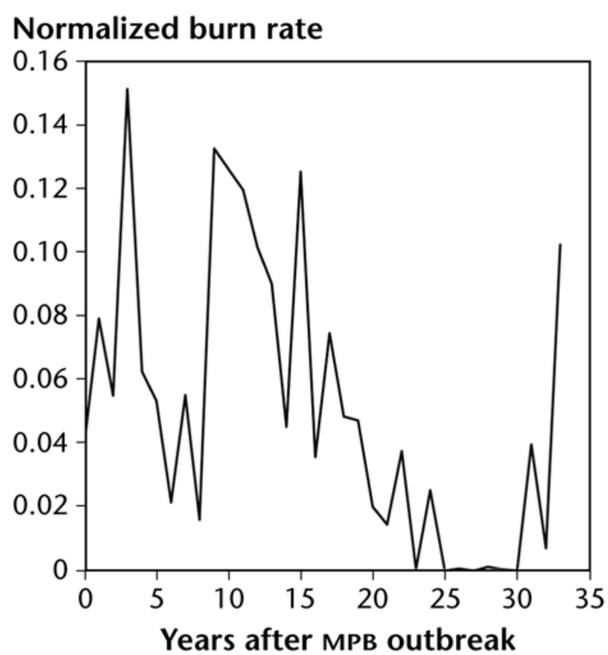

FIGURE 2. Normalized burn rate by years since outbreak for MPB in British Columbia. (Taylor *et al.* 2005).

Experimental Burning Projects: Examining Changes in Ignition Probability and Fire Behaviour After the Mountain Pine Beetle

Initiated in 2005, the Carrott Lake Mountain Pine Beetle Experimental Fire Study is conducted jointly by the B.C. Forest Service and the Canadian Forest Service with assistance from Canadian Forest Products. The study involves the experimental burning of research plots that contain lodgepole pine attacked and killed by MPB. The experimental plots range in size up to 200m^2. Two plots have been ignited to date, and a number of ignition point source test burns have taken place. The behaviour of fire in these plots was monitored to assess the hazard associated with beetle-killed stands.

The results from these experimental burns will assist fire managers to respond more effectively to fires in MPB-attacked stands, and also aid fire preparedness planning and fire behaviour forecasting. These results will also help to determine safety hazards that should be considered when responding to fires in beetle-killed pine and when conducting prescribed burns. For a project description, go to: ***http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/fire/***. See Lavoie and Taylor (2008) for a project update and some experimental burn results.

Another source of information on potential fire behaviour in MPB-affected stands comes from wildfire observations. An experimental burn project in Alberta is examining the effect of MPB on fire behavior. Alberta Sustainable Resource Development and FPInnovations, Operational Fire Research Centre, at Hinton, Alberta, are conducting experimental fires in the Archer Lake area, approximately 140 km northeast of Fort McMurray. The B.C. Ministry of Forests and Range Protection Program is also participating in this project. The project goal is to compare crown fire initiation and spread rates in live jack pine "green-attack" (first spring after death) and "red-attack" (first summer after death) plots. One-half of each plot had the jack pine girdled in 2007 to simulate MPB attack and the other half was left untreated. Two green-attack plots were ignited in 2008. In 2009, plots will be ignited to simulate fires in the red-attack stage after MPB.[1] For additional information on this project, go to: ***http://fire.feric.ca/36242007/36242007.asp***

Fuelbreaks in Stands Affected by the Mountain Pine Beetle: Example From Colorado

A recent wildfire in Colorado illustrated how fuelbreaks in MPB-affected stands can reduce structure losses. A human-caused wildfire occurred on June 25, 2007 near the YMCA Snow Mountain Ranch at Winter Park. Although fire danger conditions were only moderate, the fire grew and spread rapidly partly due to the dry beetle-killed trees that were in the red-attack stage. Following advice of the Colorado State Forest Service (CSFS) a month before the wildfire, the YMCA established a 46–61 m firebreak around several buildings that previously were nestled in the dead lodgepole pine.

The fuelbreaks reduced forest fuels adjacent to structures and in combination with a fast, co-ordinated response by firefighters, kept structures safe. The breaks also kept the fire from spreading into a neighbouring subdivision, which had about 100 homes. These fuelbreaks accomplished what foresters at the CSFS Granby District wanted them to do. When the wildfire hit the fuelbreaks, it changed from a high-intensity crown fire to a low-intensity surface fire. For more background on this fire as well as contact information, go to: ***http://www.fs.fed.us/r2/news/2008/01/press-kit/projects-partners.pdf***

B.C. Ministry of Forests and Range Protection Program, Fuel Management Program

The primary goal of the B.C. Ministry of Forests and Range's fuel management program is to manage forest fuels in the wildland-urban interface thereby reducing the potential for damage to communities from devastating wildfires. This Ministry-funded program is administered by the Union of British Columbia Municipalities. In addition, a partnership with the First Nations Emergency Services Society has been formed to provide program delivery to First Nations' communities. A 2004 provincial-level strategic threat analysis mapped interface areas, fire risk, fire behaviour potential, combined risk/fire behaviour, and spotting potential into the wildland-urban interface. For more information on the fuel management program, go to: ***http://ground.hpr.for.gov.bc.ca/***

[1] Herman Stegehuis (Alberta Sustainable Resource Development, Edmonton) is the current contact person for this project (Email: Herman.Stegehuis@gov.ab.ca; Phone: 780-415-9969).

Impacts of the Mountain Pine Beetle on First Nations

The risk of fire to communities and First Nations is potentially increased in MPB-affected lodgepole pine forests and by the woody fuels left after salvage harvesting of these forests. A number of First Nations initiatives and partnerships have been established to respond to the MPB outbreak and to protect communities from wildfires. The following summary highlights some these initiatives.

The First Nations Forestry Council (FNFC), through the First Nations MPB Fuel Management Working Group (FMWG), is taking a team approach to implementation of fuel management activities with organizations that provide funding and program delivery to First Nations communities affected by MPB. The FMWG includes the following organizations:

- First Nations Forestry Council
- First Nations Emergency Services Society
- Ministry of Forests and Range
- First Nations MPB Initiative
- Natural Resources Canada–Canadian Forest Service; and
- Indian and Northern Affairs Canada

For more information on FMWG, go to: *http://www.fnforestrycouncil.ca/initiatives_fuel.php*

The Ministry of Forests and Range, the Union of British Columbia Municipalities, and the First Nations Emergency Services Society are working to provide funding and technical assistance for First Nations communities to plan and treat MPB-affected timber adjacent to First Nations' communities. For more information on this program, go to *http://www.fness.bc.ca/Mt_Pine_Beetle/beetle.htm* and *http://ground.hpr.for.gov.bc.ca/supportforcommunities.htm*

The primary goal of the federal "Protecting Forest Resources and Communities" Program (*http://mpb.cfs.nrcan.gc.ca/protect/index_e.html*) is to reduce post-beetle threats to human safety and property risks from wildfires and dangerous dead trees. The program also assesses beetle impacts on sustaining forest and community futures, particularly as these relate to future forest values and non-timber forest use. The First Nations Wildfire Protection Element is focussed on reducing the wildland fire threat to First Nations' communities in the MPB-affected zones. For more information on this element, go to: *http://mpb.cfs.nrcan.gc.ca/protect/community/first-nations_e.html*

In 2006, the First Nations Mountain Pine Beetle Initiative (FNMPBI) was established to bring together First Nations and the governments of British Columbia and Canada in a tri-party response to the MPB outbreak. Community protection is an important priority for this partnership. For more information on FNMPBI, go to: *http://www.fnmpbi.com/* and *http://www.fnforestrycouncil.ca/initiatives_impact.php*

The FNMPBI used a "Balanced Scorecard" approach in its MPB strategic planning to identify objectives and initiatives that responded to community protection concerns in high-risk communities. Three core community protection themes examined by this process included: fuel management, emergency management, and engagement of First Nations and protection of cultural values. For examples of the objective information sheets, go to: *http://www.fnmpbi.com/documents/CommunityProtectionScorecard_FINAL.doc* and *http://www.fnforestrycouncil.ca/initiatives_res/Community_Protection_Scorecard_Executive_Summary.pdf*

Discussion Summary

After the presentation, attendees asked several questions and some discussion ensued. Some questions were raised about the variability of fuel loads in MPB-affected forests, the decomposition rates of downed trees, and the resulting effects on fire behaviour. In this regard, the range of fuel loads after MPB was discussed, as well as the American variant of the Fire and Fuels Extension (FFE) for the Forest Vegetation Simulator and what it has projected for the current MPB outbreak over the next 30 years. Also discussed were differences in climate regimes across the province and how changes in site moisture and downed tree elevation above the snowpack can affect decomposition.

Another question related to priorities for fuel management based on location and the allocation of treatment funds—certain areas would receive top priority for treatment based on the time since MPB mortality and the fuel condition stage (e.g., red-attack versus grey-attack stage). Even though stands in the grey-attack stage may have a reduced probability of crowning compared to those in the red-attack stage, dead lodgepole pine will eventually fall down increasing surface fuel loads, which could result in an increase in fire intensity and crowning of the remaining live trees.

Attendees expressed concern about the increased fire risk in and around British Columbia communities in relation to MPB-affected areas, especially for First Nations' communities. One attendee enquired about actions necessary to deal with fuel loads in interface areas. The first step is to develop a fire and fuel management plan for the community that outlines specific fuel treatments.

Finally, attendees discussed the apparent lack of broad-spectrum ground rules on how to manage MPB-related increases of forest fuels. To develop fuel treatment options, fire experts will need to undertake a case-by-case analysis of the fuel conditions.

References

Duffy, C. 2008. Fuel management and mountain pine beetle. BC Forestry Professional Magazine July/August. URL: ***http://www.abcfp.ca/publications_forms/BCFORmagazine/documents/ForestPro_July_Aug_Final.pdf***

Duffy, C. and S. Harvey. 2008. Mountain pine beetle fire operations and fuel management. Provincial Emergency Preparedness Program and B.C. Ministry of Forests and Range, Protection Program, Prince George Fire Centre, Prince George, B.C. Presentation given to "National Conversation on Forest Fire Management" series produced by the Canadian Interagency Forest Fire Centre, Science and Technology Working Group. URL: ***http://ciffc.ca/templates/ciffc2/content/presentation3.pdf***

Hawkes, B.C., S.W. Taylor, C. Stockdale, T.L. Shore, R.I. Alfaro, R.A. Campbell, and P. Vera. 2004. Impact of mountain pine beetle on stand dynamics in British Columbia. *In* Mountain pine beetle symposium: Challenges and solutions, October 30–31, 2003, Kelowna, B.C. T.L. Shore, J.E. Brooks, and J.E. Stone (editors). Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, B.C. Information Report BC-X-399. pp. 177–199. URL: ***http://warehouse.pfc.forestry.ca/pfc/25048.pdf***

Hawkes, B.C., S.W. Taylor, C. Stockdale, T.L. Shore, S.J. Beukema, and D. Robinson. 2005. Predicting mountain pine beetle impacts on lodgepole pine stands and woody debris characteristics in a mixed severity fire regime using Prognosis[BC] and the fire and fuels extension. *In* Mixed severity fire regimes: Ecology and management, November 17–19, 2004, Spokane, Wash. L. Lagene, J. Zelnik, S. Cadwallader, and B. Hughes (editors). Washington State University Coop Extension Service and the Association for Fire Ecology, Pullman, Wash., Vol. AFE MISC03. pp. 123–135. URL: ***http://warehouse.pfc.forestry.ca/pfc/25427.pdf***

Lavoie, N. and B. Hawkes. 2008. Action on the interaction: Mountain pine beetle and fire. BC Forestry Professional Magazine July/August. URL: ***http://www.abcfp.ca/publications_forms/BCFORmagazine/documents/ForestPro_July_Aug_Final.pdf***

Lavoie, N. and S. Taylor. 2008. Effects of mountain pine beetle on fuel loading and fire behaviour. B.C. Ministry of Forests and Range, Protection Program, and Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, B.C. Presentation given to "National Conversation on Forest Fire Management" series produced by the Canadian Interagency Forest Fire Centre, Science and Technology Working Group. URL: ***http://ciffc.ca/templates/ciffc2/content/presentation2.pdf***

Taylor, S.W., G. Thandi, and B. Hawkes. 2005. Interactions between wildfire and forest insect outbreaks in British Columbia. Forest Science Program Project Y05-01233, Annual Technical Report Supplement 1. URL: ***http://www.for.gov.bc.ca/hfd/library/FIA/2005/FSP_Y051233b.pdf***

Whitehead, R.J., G.L. Russo, B.C. Hawkes, S.W. Taylor, B.N. Brown, O.B. Armitage, H.J. Barclay, and R.A. Benton. 2008. Effect of commercial thinning on within-stand microclimate and fine fuel moisture conditions in a mature lodgepole pine stand in southeastern British Columbia. Canadian Forest Service, Canadian Wood Fibre Centre, Ottawa, Ont. Info. Rep. FI-X-004. URL: ***http://warehouse.pfc.forestry.ca/pfc/29063.pdf***

Popular Summary

Mountain pine beetle increases the complexity of fire-origin lodgepole pine stands in British Columbia, Canada

René Alfaro[1], Jodi Axelson[2], and Brad Hawkes[3]

Presentation Abstract

As a natural agent of disturbance, beetle outbreaks play an important functional role in directing ecological processes and maintaining biological diversity of forest ecosystems. The mountain pine beetle (*Dendroctonus ponderosae* Hopkins; MPB) is the major natural disturbance agent affecting lodgepole pine (*Pinus contorta* Dougl.) forests in British Columbia, Canada. With the current outbreak covering almost 10 million ha, forest managers need post-outbreak strategies to manage the large areas left unsalvaged. To develop these strategies, they need information on stand-dynamic processes associated with mountain pine beetle outbreaks, such as host mortality, and post-outbreak stand growth, recruitment rates, and species composition. We examined the dynamics of lodgepole pine in even-aged and uneven-aged stands in the central interior of British Columbia, which is currently undergoing beetle outbreaks. Using historical ecology approaches, dendrochronology, and stand inventory data, we were able to determine the roles that fire and repeated MPB disturbances have played in maintaining the ecological complexity of lodgepole pine in these ecosystems. We found that stand-replacing fires initiated seral even-aged lodgepole pine stands, while multiple mixed-severity fires initially created patchy uneven-aged stands. Selective tree killing by repeated MPB disturbances increased the complexity of these ecosystems.

KEYWORDS: *dendrochronology, mountain pine beetle, natural disturbance agent, stand-dynamic processes, stand-replacing fires.*

Contact Information

1 Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, 506 West Burnside Road, Victoria, BC V8Z 1M5. Email: ralfaro@pfc.forestry.ca

2 Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, 506 West Burnside Road, Victoria, BC V8Z 1M5. Email: jaxelson@pfc.forestry.ca

3 Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, 506 West Burnside Road, Victoria, BC V8Z 1M5. Email: bhawkes@pfc.forestry.ca

Alfaro, R., J. Axelson, and B. Hawkes. 2008. Mountain pine beetle increases the complexity of fire-origin lodgepole pine stands in British Columbia, Canada. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):85–89.
URL: *http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf*

Rationale

Mountain pine beetles are a natural disturbance of North American forests and outbreaks play an important role in directing ecological processes and maintaining the biological diversity of forest ecosystems. However, having infested over 10 million ha of lodgepole pine forests in British Columbia to date, the current beetle outbreak seems unprecedented in its scale. As lodgepole pine represents about one-quarter of the provincial timber supply, the socio-economic impacts of this outbreak are enormous. Various 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 losses. Because of market, operational, legal, and ecological constraints, the proportion of the beetle-killed forests that can be salvage-logged is limited.

Throughout much of British Columbia, lodgepole pine forms 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 common in central British Columbia. Forest landscapes in this area are dominated by lodgepole pine and can generally be described as a mosaic of even-aged and uneven-aged stands. Nevertheless, 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 little about the changes in forest characteristics following beetle outbreaks.

Project Objectives

Our project had the following three objectives:

1. to understand the current stand structure of even- and uneven-aged lodgepole pine stands;
2. to reconstruct stand dynamics following beetle outbreaks in even-aged stands in the southern (Logan Lake) and uneven-aged stands in the central interior (Chilcotin Plateau) of British Columbia (Figure 1); and
3. to develop conceptual models of stand dynamics that incorporate beetle and fire disturbances.

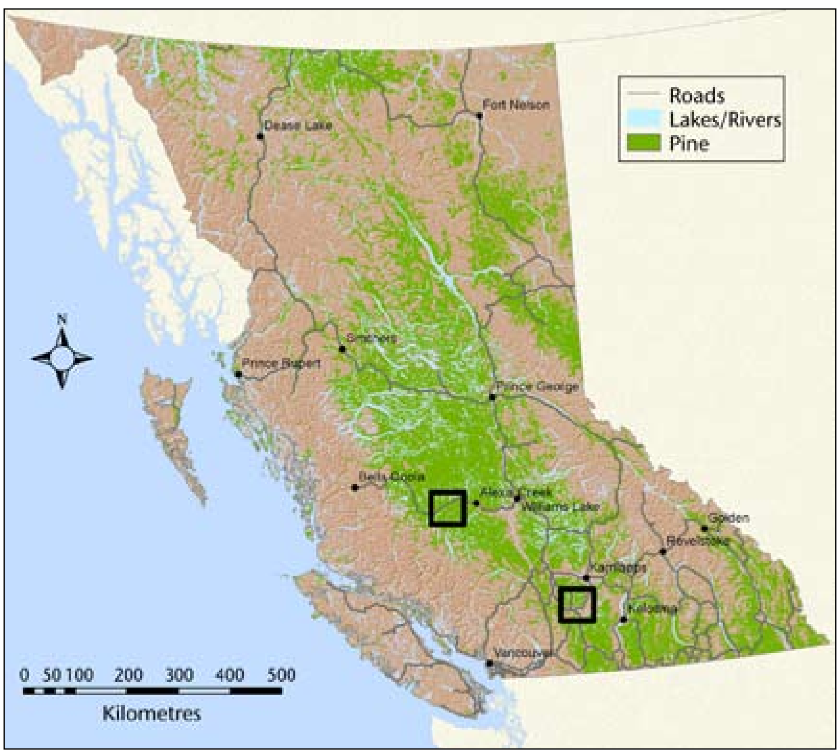

FIGURE 1. Range of lodgepole pine in British Columbia and location of sample areas.

Methods

We used forest inventory techniques to determine present stand structure and post-beetle legacies by taking a number of measurements, such as:

- diameter at breast height,
- tree height, and
- mountain pine beetle attack status (i.e., no attack, green attack [current year], red attack [attacks occurred 2–3 years before], or grey attack [attacks occurred more than 3 years ago]).

We used dendrochronology techniques to determine past stand structure by collecting tree increment cores and discs from dominant trees, saplings, and dead downed trees (coarse woody debris). We then used tree-ring pattern-matching to accurately date each ring in every sample to determine times of past beetle episodes, past fire disturbances, year of tree establishment, and year of death (Figure 2). Some wildfires and MPB attacks leave permanent records in the form of scars on the tree bole. Past MPB outbreaks are identified in the tree ring record of surviving trees as sustained periods of accelerated growth ("releases"), which are caused by canopy removal by the beetle.

Results

Reconstructing Forest History

Fire History

After careful dating of tree rings, we identified the year in which a fire or MPB attacks occurred. Based on this information, we found that stands in even-aged forests were initiated by a single stand-replacing event (crown fires) in the late 1800s or the early 1900s. In the uneven-aged stands, we found that many less severe fires had occurred, leaving multiple scars on surviving trees, but not necessarily eliminating the entire stand.

Mountain Pine Beetle Outbreak History

Under epidemic conditions, MPB preferentially kills the largest trees in the stand. Under intense beetle pressure, this will result in the mortality of all or almost all of the mature trees within a given stand. The trees that are killed by MPB turn red (about 2 years after the initial attack); the needles then fall off leaving a denuded tree that has a grey appearance (3–6 years). Dead trees eventually fall to the ground and become coarse woody debris. The removal of the tree foliage allows much more light to reach the ground creating an environment that supports regeneration. After the outbreak, trees that survive normally sustain a period of accelerated growth, which is the result of reduced competition for light and other resources.

FIGURE 2. (a) Collecting cores to establish stand chronologies; and (b) Cutting a disc from coarse woody debris to date year of death and extend stand chronologies back in time.

We reconstructed past beetle outbreaks by looking for sustained (greater than 5 years) periods of growth release in the tree-ring record. We quantified the growth release using an increased growth factor (e.g., a 50% increase in mean radial growth, recorded by a percentage of trees sampled in the stand). In both even- and uneven-aged stands, residual trees experienced a greater than 50% increase in annual growth during the 1930s, 1960s, and 1980s. These dates all coincided with known periods of beetle outbreak as recorded by the Forest Insect and Disease Survey of the Canadian Forest Service.

Forests Today

Forest Structure

Examination of the diameter at breast height (DBH) and height distributions of the sample stands revealed the prevalence of different forest layers, or cohorts, in both the even- and uneven-aged forests (Table 1).

In the even-aged stands, the largest and oldest trees were very large, veteran Douglas-fir trees that survived stand-replacing fires in the late 1800s and early 1900s. The dominant canopy, which initiated after stand-replacing fires, contained the oldest pine in the stand. Below this layer, a lodgepole pine-dominated sub-canopy occurred that was initiated after the beetle outbreak of the 1930s had thinned the dominant canopy. An advanced regeneration layer also occurred that initiated after the 1980s outbreak. Some seedlings were present, initiating around 2004–2005 (i.e., in response to the current outbreak), but these were infrequent because of the low light conditions still prevalent at the forest floor.

In the uneven-aged stands, no Douglas-fir veterans were present. Therefore, the oldest trees in the dominant canopy were lodgepole pines. Because of the mixed-severity fire regime of this area, many pine trees survived ground fires and as a result did not establish in one single regeneration pulse (as in the even-aged stands). Also present in the dominant canopy were trembling aspen, which likely established after ground-fire events. The next sub-canopy layer contained both pine and aspen, which were both largely initiated after beetle outbreaks of the 1930s and 1960s. Similar to the even-aged stands, the advanced regeneration layer initiated after the 1980s outbreak. Numerous seedlings were present (Figure 3), initiating around 2004–2005, as ample light was present in these stands because of the open canopy with few live, mature pine trees.

FIGURE 3. Seedlings established in response to increased light reaching the ground after canopy trees died due to mountain pine beetle attack in British Columbia's Chilcotin Plateau.

Stand Development After Beetle

Mountain pine beetle is a natural thinning agent that promotes increased growth among the surviving trees and allows for establishment of seedlings in the understorey. In all sampled stands, the sub-canopy

TABLE 1. Composition and tree density in even- and uneven-aged lodgepole pine stands under attack by the mountain pine beetle in the interior of British Columbia. Figures are presented for the two main layers (dominant canopy and sub-canopy). Two other layers were also present: advanced regeneration and seedling layer (see text).

	Live and dead (sph[a])	Mean DBH (cm)	Mean height (m)	Species (%)[b]	Pl live and dead (sph)	Live Pl (sph)	Live Pl (%)
Dominant canopy							
Even-aged	2525	12.54	13.64	3 Fd; 97 Pl	2450	833	34
Uneven-aged	1130	13.41	11.00	3 At; 97 Pl	1096	592	54
Sub-canopy							
Even-aged	1508	4.55	6.54	12 Fd; 87 Pl; 1 Sx	1312	328	25
Uneven-aged	2034	3.08	3.72	24 At; 76 Pl	1545	1035	67

[a] sph = stems per hectare

[b] Species abbreviations: Fd = Douglas-fir; Pl = lodgepole pine; Sx = spruce; At = trembling aspen.

layer, which consisted of a well-developed cohort in both even- and uneven-aged stands, was mainly free of beetle attack and will endure after the dominant canopy has been killed and falls to the ground. The advanced regeneration layer was present, and along with the sub-canopy, forms an important secondary structure, showing that the entire forest was not all dead.

Putting it all Together

Forest disturbances, such as wildfire and MPB outbreaks, are natural processes that operate at the stand or landscape level. We were able to develop conceptual models of stand dynamics in lodgepole pine ecosystems in British Columbia. These models show that, in the absence of fire, mountain pine beetle plays a more important and frequent role in determining forest structure and species composition in both the southern and central interior regions of British Columbia. These models are used to project timber supply.

Conclusion

- In the absence of fire disturbance, the MPB plays a more frequent role in directing stand dynamics and structure in the lodgepole pine stands of British Columbia.
- Stand-replacing fires initiate even-aged seral lodgepole pine stands; multiple MPB disturbances create stands that have variable canopy and cohort structure, and contribute to the succession of non-pine tree species that are shade tolerant (e.g., Douglas-fir and interior spruce).
- Mixed-severity fires create complex structures in uneven-aged lodgepole pine stands; multiple MPB disturbances maintain complex stand structures and contribute to the succession of pine and non-pine tree species (e.g., trembling aspen) resulting in a persistent lodgepole pine ecosystem.
- Frequency and severity of MPB outbreaks determines the structure and composition of the residual stand.

Acknowledgements

We wish to thank the Forest Investment Account–Forest Science Program of British Columbia for funding this 2-year project and the following Pacific Forestry Centre staff for their assistance and contributions: Andrew Copeland, Lara van Akker, Sarah Buddingh, Victoria Alfred, Thandi Gurp, Terry Holmes, and Mark Lindal.

Abstract

Predicting the distribution of advance regeneration and secondary structure in the pine-dominated forests of British Columbia's Sub-Boreal Spruce zone

Philip J. Burton[1] and Darin W. Brooks[2]

Presentation Abstract

Considerable uncertainty surrounds the recovery and future composition of lodgepole pine stands in the wake of the mountain pine beetle. Large areas of beetle-affected forest will not be harvested or managed in the foreseeable future. Some forests have a considerable non-pine component, and it is suggested that these forests be deferred from logging because they have potential for unassisted recovery and growth. While forest cover maps provide some indication of the extent of the overstorey non-pine component, no inventory exists of seedlings and saplings found in the understorey. We report on 3 years of field sampling and the analysis of 1690 ground plots (collated from multiple sources) collected from pine-leading stands in the Sub-Boreal Spruce biogeoclimatic zone. Although the density of various species and size classes of conifer regeneration exhibit significant relationships with local factors such as site series and canopy openness, only factors available as mapped data could be used in predictive models. To this end, relationships were developed for each biogeoclimatic subzone utilizing factors such as overstorey composition, stand age, distance from various seed sources, and interpolated climate normals derived using ClimateBC. Various models were developed based on categorical differences, multiple regression, and logistic regression. Alternative projections of understorey conifer density, probability of meeting clearcut stocking standards, and deviation from potential (DFP) stocking are presented for the same mapped area. Issues of model uncertainty and independent validation are discussed along with public availability of mapped model output. The results of this research should be of great utility in planning harvest scheduling and in being able to meet new standards for understorey protection.

KEYWORDS: *advance regeneration, deviation from potential, forest regeneration, secondary structure, spatial modelling, stand dynamics, stocking.*

Contact Information

1 University of Northern British Columbia, Ecosystem Science and Management, and Canadian Forest Service, 3333 University Way, Prince George, BC V2N 4Z9. Email: pburton@nrcan.gc.ca

2 University of Northern British Columbia, Ecosystem Science and Management, 3333 University Way, Prince George, BC V2N 4Z9. Email: kfmgis@telus.net

Burton, P.J. and D.W. Brooks. 2008. Predicting the distribution of advance regeneration and secondary structure in the pine-dominated forests of British Columbia's Sub-Boreal Spruce zone. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):90. URL: *http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf*

Abstract

A framework for documenting the effects of the mountain pine beetle outbreak in sub-boreal forests of northern British Columbia: Two years following establishment

Craig DeLong[1] and Bruce Rogers[2]

Presentation Abstract

In 2005 through 2007, 48 plots were established in mature pine-leading stands affected by mountain pine beetle (MPB) (38 plots) and MPB followed by wildfire (10 plots). All plots will remain unharvested, and are designed to examine ecological changes subsequent to these disturbances. The data from these plots will track the ecological changes resulting from these disturbances in the sub-boreal forest landscape, and will offer critical information (such as growth rate of live understorey) to land managers. Data from these randomly located permanent sample plots will also supply answers to a wide range of questions relating to MPB stand and ecosystem dynamics. This project will provide a much-needed understanding of: (1) ecological changes and value of unique stand features (e.g., wildlife trees) of unsalvaged and burned unsalvaged MPB stands; (2) forest regeneration and non-crop vegetation dynamics of unmanaged and burned MPB stands; (3) timber supply (regeneration delay, growth and yield) and biodiversity implications of unharvested MPB stands; (4) relative ecological and economic (timber supply) benefits of burning unharvested MPB stands; (5) windthrow and decomposition dynamics of pine trees killed by MPB; and (6) changes in lichen abundance and rate of tree fall as they affect caribou habitat quality. Two years following plot establishment, all lodgepole pine greater than 27.5 cm DBH were dead; in 98% of the cases mortality was caused by MPB. All sites had some live trees within one of the regeneration layers. Height growth response to overstorey canopy death was significantly positive for advance regeneration of all species. Lodgepole pine seedling establishment in burnt-over sites far exceeded that of non-burned sites.

KEYWORDS: *mountain pine beetle, natural regeneration, secondary structure, stand dynamics, understorey release.*

Contact Information

1 British Columbia Ministry of Forests and Range, 1011 4th Avenue, Prince George, BC V2M 7B9.
Email: craig.delong@gov.bc.ca

2 British Columbia Ministry of Forests and Range, 1011 4th Avenue, Prince George, BC V2M 7B9.
Email: bruce.rogers@gov.bc.ca

DeLong, C. and B. Rogers. 2008. A framework for documenting the effects of the mountain pine beetle outbreak in sub-boreal forests of northern British Columbia: Two years following establishment. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):91. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Abstract

The forest is alive after mountain pine beetle attack

Kyle Runzer[1] and Chris Hawkins[2]

Presentation Abstract

British Columbia's lodgepole pine (*Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm.) forests are experiencing a mountain pine beetle (*Dendroctonus ponderosae* Hopkins; MPB) epidemic. Some have suggested the forest is dead after attack and must be rehabilitated. Over three field seasons, we sampled 459 age class 1–8 stands within nine Sub-Boreal Spruce subzones in the Prince George Timber Supply Area. Our objectives were to quantify MPB attack and document beetle-induced changes in stand structure and composition. At the landscape level, attack rates increased with age class and almost all pine was killed in the older age classes. Residual basal area after attack was similar for age class 1 to 6, but was marginally greater for age classes 7 and 8. Residual trees in immature age classes are predominantly lodgepole pine, whereas in the mature age classes, a much greater residual mature tree species diversity exists.

The majority of temporary sample plots, in immature and mature stands, have adequate regeneration to be considered stocked even if all the tree-layer pine were to succumb to the MPB. However, in some instances, regeneration would result in mixed broadleaf-conifer stands or less desirable conifer stand species composition. On average, the dry and mesic subzones were dominated by lodgepole pine and hybrid spruce regeneration. Regeneration in wetter subzones was predominantly hybrid spruce, subalpine fir, and lodgepole pine. Minor amounts of trembling aspen and black spruce regeneration were found in all subzones and age classes. Attack rate, residual tree layer, and secondary structure are highly variable. As a result, management decisions should be made at the stand level. Across all age classes, many of the attacked stands are not dead and could contribute to the short-, mid- and longer-term timber supply.

KEYWORDS: *complex stands, secondary structure, management.*

Contact Information

1 Mixedwood Ecology and Management Program, University of Northern British Columbia, 3333 University Way, Prince George, BC V2N 4Z9. Email: hawkinsc@unbc.ca

2 Mixedwood Ecology and Management Program, University of Northern British Columbia, 3333 University Way, Prince George, BC V2N 4Z9. Email: runzerk@unbc.ca

Runzer, K. and C. Hawkins. 2008. The forest is alive after mountain pine beetle attack. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):92. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

A hybrid modelling approach to estimating establishment and growth of advanced regeneration following mountain pine beetle attack

Derek F. Sattler[1], Valerie LeMay[2], and Peter Marshall[3]

Presentation Abstract

A hybrid model that links modules of SORTIE-ND and Prognosis^{BC} is described. The impetus to develop this model has come in response to the need for a dynamic management tool that can provide reasonably accurate estimates of growth for stands that have been attacked by mountain pine beetle (MPB), but will go unsalvaged. The rapid change in stand structure following disturbance events such as MPB infestation challenges our ability to use traditional growth and yield models. Generally, these models rely heavily on historical field measurements to establish empirically based relationships describing diameter distributions and tree growth. Models of this type run into problems when a limited amount of historical data is available, and rapidly changing and variable conditions within the stand make it difficult to establish empirical relationships that provide acceptable levels of prediction accuracy.

Linking modules of SORTIE-ND with Prognosis^{BC} brings together empirical and process-based methods. The hybrid (linked) model operates on two main assumptions: (1) the relationships related to adult tree growth described using empirical means remain relatively intact following disturbance; and (2) seedling establishment and growth are best described through a process-based approach. The model is evaluated by comparing projections of stand density, diameter distribution, and species composition against actual measurements from stands that were attacked by MPB roughly 25 years ago. Overall, prediction accuracy for the hybrid model was better than simulations run using SORTIE-ND and Prognosis^{BC} independently. Improved model accuracy is discussed with specific reference to changes in the crown architecture in SORTIE-ND.

KEYWORDS: *crown architecture, hybrid model, natural regeneration, Prognosis^{BC}, SORTIE-ND.*

Contact Information

1 Forest Resources Management, University of British Columbia, 2424 Main Mall, Vancouver, BC V6T 1Z4.
Email: sattler@interchange.ubc.ca

2 Forest Resources Management, University of British Columbia, 2424 Main Mall, Vancouver, BC V6T 1Z4.
Email: valerie.lemay@ubc.ca

3 Forest Resources Management, University of British Columbia, 2424 Main Mall, Vancouver, BC V6T 1Z4.
Email: peter.marshall@ubc.ca

Sattler, D.F., V. LeMay, and P. Marshall. 2008. A hybrid modelling approach to estimating establishment and growth of advanced regeneration following mountain pine beetle attack. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):93–97. URL: *http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf*

Introduction

In the wake of the current mountain pine beetle (*Dendroctonus ponderosae* Hopkins; MPB) outbreak, harvesting operations have been firmly focussed on the recovery of timber from beetle-affected stands (Hawkes *et al*. 2004). However, because of limits in the shelf-life and the industrial capacity to process recovered logs, a large proportion of MPB-affected stands will go unsalvaged (Nelson *et al*. 2006). It is from these unsalvaged stands that we expect to obtain much of the province's mid- and long-term timber supply (Coates and Hall 2005). Traditionally, we have relied on empirically based growth and yield models to provide estimates of future timber volume (Makela 2003). In the face of rapidly changing forest conditions such as we are seeing with the current MPB outbreak, the reliability of empirically based estimates can become compromised as observed conditions no longer match historical data. Thus, the relatively rapid pace of change in forest structure following MPB attack has placed considerable importance on the need to develop dynamic quantitative growth and yield models, commonly referred to as hybrid models. Within a hybrid model system, estimates of future tree growth and stand conditions are obtained through a feedback system between empirical predictions and process-based predictions, the latter of which model the basic building blocks related to tree growth (Makela 2003; Robinson and Ek 2003).

Here, we present a dynamic method for estimating the growth and yield of stands that have been attacked by MPB yet have remained unsalvaged and unmanaged. Our focus was on the integration of two models, the empirical Prognosis^{BC} model, and the light-mediated, process-based SORTIE-ND model. The specific objective was to test whether accurate predictions of future forest growth following MPB attack could be achieved using the recruitment sub-model of SORTIE-ND as a means to dynamically populate Prognosis^{BC} with trees less than 7.5 cm in diameter at breast height (DBH).

Management implications directly associated with this project are manifold. To begin with, a hybrid model that combines the strengths of the process-based and empirical functions of SORTIE-ND and Prognosis^{BC} would be a very useful tool for the projection of mid- to long-term yields. Secondly, the structure of the hybrid model allows forest managers to explore different scenarios for the regeneration of MPB-affected stands. This sort of exploration would be extremely useful in identifying stands that are suitable for underplanting, as described by Coates and Hall (2005). Lastly, the hybrid model could be used to obtain estimates of the expected volume of stands currently guarded from current salvage operations to protect an understorey that is likely to reach merchantable limits in 30–50 years.

Methodology Overview

Data for Analysis

The research conducted for this project focussed on MPB-attacked stands in the central interior (Quesnel/Williams Lake) region of British Columbia. Stands selected for sampling included pine-dominated stands that showed clear evidence of historic MPB attack. In the majority of the sampled area, the most recent severe attacks occurred 25 years ago. Stand structure at the time of attack (referred to as "Time 1") was estimated through the tree reconstruction methods described in LeMay *et al*. 2006. The reconstructed trees were used to populate SORTIE-ND and Prognosis^{BC}, while the measurements from 2006 (referred to as "Time 3") were used to calculate bias and root mean square error of the final model predictions. We intentionally reserved the use of "Time 2" here, as it is later used to denote a specific point in time between "Time 1" and "Time 3."

Adjustments to the Parameters and Sub-models of SORTIE-ND

Parameters for the allometry and substrate behaviours in SORTIE-ND were estimated using the data collected from the Williams Lake area. All remaining parameters for SORTIE-ND behaviours were obtained from published literature, personal communication, and the Bulkley Valley Research Centre (Astrup *et al*. 2007). Initial tests of the SORTIE-ND crown allometry equations were conducted to determine whether predictions fell within the upper and lower bounds of acceptable error. Based on these results, and the knowledge gained from historical data and previous literature (e.g., Staudhammer and LeMay 2000; Temesgen *et al*. 2005), we proposed alternative equations to estimate crown height and crown width. The new equations were developed to:

1. improve the functional form of the model;
2. ensure logical consistency in the estimates; and
3. include indices of plant competition as predictors of crown length and crown radius.

Linking SORTIE-ND and Prognosis^{BC}

To test the hypothesis that a linkage between SORTIE-ND's recruitment sub-model and Prognosis^{BC}'s growth models would provide the "best" estimates of growth and yield over a 25-year period, a transfer of regeneration tree-list data between the models was evaluated at three different time periods (5, 10, and 15 years following MPB attack). The model flow of the stand-level simulations can be segmented into four main steps:

1. tree lists representing the overstorey (O/S) and understorey (U/S) stand structure shortly after MPB attack (Time 1) are inputted to SORTIE-ND and Prognosis^{BC};
2. tree lists are then projected to Time 2 using each model;
3. at Time 2, the understorey trees produced via recruitment in SORTIE-ND are added to the projected tree list from Prognosis^{BC}; and
4. the augmented tree lists are then projected to Time 3 using Prognosis^{BC}, assuming no further disturbance nor recruitment.

Model outputs following stage 4 were compared to actual data and assessed for their accuracy in terms of density, measured through stems per hectare and basal area per hectare.

Overview of Results and Discussion

Crown Allometry in SORTIE-ND

In fitting crown length and crown radius using weighted three-stage least square regression methods, we were able to take advantage of the inherently strong relationship that exists between these two crown axes and improve the prediction accuracy for a range of stand densities. Prediction accuracy for each species is presented in Table 1. For all species, the regression models tended to overestimate crown length and crown radius. In addition to using crown length and crown radius as dependent regressors, individual tree-level variables selected for model inclusion were diameter at breast height, total tree height, and basal area of trees taller than the target tree. Stand-level variables included in the models were stems per hectare and basal area per hectare. When compared to predictions derived using non-linear least squares regression, modelling crown length and crown radius as a system improved crown dimension estimates for all four species tested:

- pine (*Pinus contorta* Dougl. ex Loud. var. *latifolia*),
- Engelmann spruce (*Picea engelmannii* × *glauca* [Moench] Voss),
- Douglas-fir (*Pseudotsuga menziesii* var. *glauca* [Beissn.] Franco), and
- aspen (*Populus tremuloides* Michx.).

To examine the variability explained through the use of stand-level measures of density within the new equations, partial model R^2 values were calculated. Notable partial R^2 values were observed for estimates of crown radius for pine (partial R^2 = 0.12), spruce (partial R^2 = 0.1) and the crown length of aspen (partial R^2 = 0.4). These results supported the inclusion of the stand-level measures of density when predicting crown length and crown radius.

Within SORTIE-ND, use of the newly developed crown equations resulted in slightly lower Global Light Index (GLI – the percentage of full sunlight received at a point) values within the seedling stratum (measured in SORTIE-ND using Quadrat GLI behaviour) 10 years after the start of the simulation. Using the new crown equations, mean GLI values for the tested stand were 22.05; using the standard SORTIE-ND crown allometry equations, the mean GLI value was 18.02.

TABLE 1. Root means square error values (metres) for crown length and crown radius using weighted three-stage least squares regression.

Dependent variable	Spruce	Pine	Douglas-fir	Aspen
Crown length	1.0656	1.0177	1.1361	1.1403
Crown radius	0.1584	0.1548	0.2613	0.1437

Twenty-five Year Simulation Using Linked Model Approach

The transfer of advanced regeneration below 7.5 cm DBH from SORTIE-ND to Prognosis^{BC} 15 years after the initiation of stand simulations ("Time 1") provided the best results for estimated stems per hectare and basal area per hectare among the three time periods tested. The results also provided improved estimates when compared to simulations run using SORTIE-ND and Prognosis^{BC} independently. Of the eight stands tested, estimates of stems per hectare for trees less than 5 cm DBH were far less accurate than the densities estimated for trees in larger diameter classes. Regardless of when the transfer of advanced regeneration took place, the

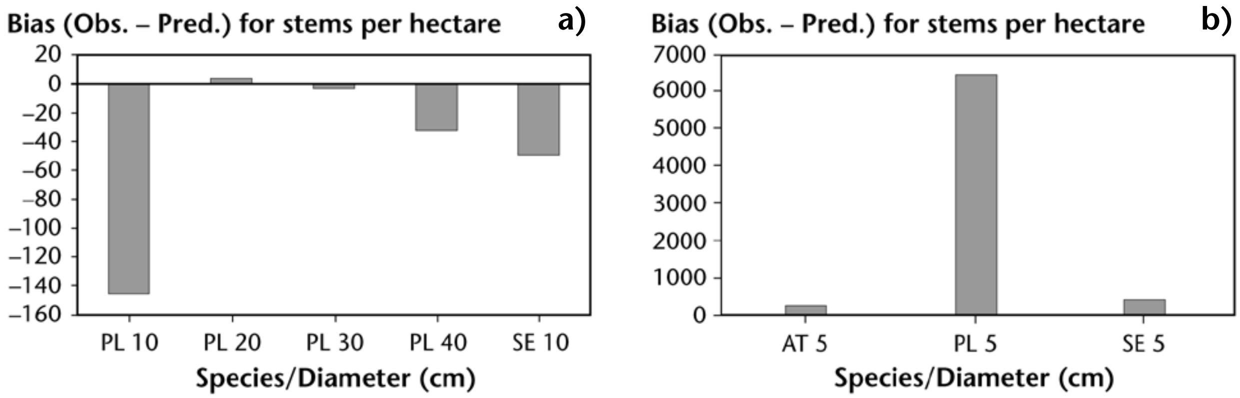

FIGURE 1. Bias for stems per hectare in Stand 3 resulting from transfer of SORTIE-ND advanced regeneration to Prognosis^{BC} at year 15 for (a) the 10–40 cm diameter classes and (b) the 5 cm diameter class. Negative values on the *y*-axis represent cases where the model overestimated the number of stems per hectare. Species codes: PL = pine; AT = aspen; and SE = hybrid spruce.

hybrid model approach tended to largely underestimate the amount of advanced regeneration observed on the sample sites. Estimates of stems per hectare and basal area per hectare for trees in larger-diameter classes showed greater congruency with observed densities. Figure 1 shows results from one of the sampled stands.

Although estimates of stems per hectare and basal area per hectare may be within acceptable limits for larger trees, parameterization of all SORTIE-ND behaviours to the study area is likely required before improved estimates of trees below 5 cm DBH are observed. If the hybrid modelling approach results in acceptable accuracy in estimation for all tree sizes, steps could then be taken to implement the model in other MPB-affected stands outside the study area, and to investigate the use of this hybrid modelling approach for other disturbance types.

References

Astrup, R., D.K. Coates, E. Hall, and A. Trowbridge. 2007. Documentation of the SORTIE-ND SBS research parameter file version 1.0. February, 2007. Bulkley Valley Centre for Natural Resources Research and Management, Smithers, B.C.

Coates, D.K. and E.C. Hall. 2005. Implications of alternative strategies in mountain pine beetle damaged stands. Bulkley Valley Centre for Natural Resources Research and Management, Smithers, B.C. Technical report for Forest Science Program Project Y051161.

Hawkes, B., S. Taylor, C. Stockdale, T.L. Shore, R.I. Alfaro, R. Campbell, and P. Vera. 2004. Impacts of mountain pine beetle on stand dynamics in British Columbia. *In* Mountain pine beetle symposium: Challenges and solutions. Kelowna, B.C. October 30–31, 2003. T.L. Shore, J.E. Brooks, and J.E. Stone (editors). Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, B.C. Information Report BC-X-399. pp. 175–195.

LeMay, V., T. Lee, R.E. Scott, D. Sattler, D. Robinson, A-A. Zumrawi, and P. Marshall. 2006. Modeling natural regeneration following mountain pine beetle attacks in the southern and central interior of British Columbia: Results for year 1. Internal report for Natural Resources Canada, MPB Standard Contribution Agreement, PO#8.35.

Makela, A. 2003. Process-based modeling of tree and stand growth: Towards a hierarchical treatment of multiscale processes. Canadian Journal of Forest Research 33:398–409.

Nelson, T., B. Boots, M.A. Wulder, T. Shore, L. Safranyik, and T. Ebata. 2006. Rating the susceptibility of forest to mountain pine beetle infestations: The impact of data. Canadian Journal of Forest Research 36:2815–2825.

Robinson, A. and A.R. Ek. 2003. Description and validation of a hybrid model of forest growth and stand dynamics for the Great Lakes region. Ecological Modelling 170:73–104.

Staudhammer, C. and V.M. LeMay. 2000. Height prediction equations using diameter and stand density measures. Forestry Chronicle 76(2):303–309.

Temesgen, H., V. LeMay, and S. Mitchell. 2005. Tree crown ratio models for multi-species and multi-layered stands. Forestry Chronicle 81(1):133–141.

Valentine, H.T. and A. Makela. 2005. Bridging process-based and empirical approaches to modeling tree growth. Tree Physiology 25:769–779.

Popular Summary

Sampling secondary structure on novel aerial photographs

Pat Teti[1]

Presentation Abstract

Residual live conifers in beetle-attacked pine stands are important because they can provide various non-timber benefits in addition to the potential for mid-term timber supply. However, spatial data on the sizes and stem densities of this "secondary structure" are generally unavailable, thereby making it difficult to retain stands that meet objectives. Collecting this information currently requires field sampling because secondary structure cannot be reliably detected on standard aerial photosgraphs. Live conifers are visible under a pine canopy if aerial photographs are acquired when snow covers the forest floor and the sky is overcast. The accuracy of sampling live understorey conifers in beetle-attacked pine stands using this method is being tested in 2008. Preliminary results indicate that live fir and spruce trees in a mature, attacked pine stand can be reliably counted and measured if crowns are at least 1 m in diameter.

KEYWORDS: *pine beetle, remote sensing, secondary structure.*

Contact Information

1 B.C. Ministry of Forests and Range, Southern Interior Region, 200–640 Borland Street, Williams Lake, BC V2G 4T1. Email: pat.teti@gov.bc.ca

Teti, P. 2008. Sampling secondary structure on novel aerial photographs. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):98–100. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Introduction

In 2005, British Columbia's Chief Forester recommended increased retention levels during pine-salvage operations, especially live understorey and non-pine mature trees. Live conifers remaining in a beetle-attacked pine stand are referred to as "secondary structure" by Coates *et al.* (2006). An amendment to the Forest Planning and Practices Regulation (Province of British Columbia 2008) requires forest licensees to retain secondary structure in targeted pine-leading stands where certain criteria are met. However, for professionals to efficiently implement these practices, they will need information about secondary structure that is not generally available in the provincial inventory. These data can be obtained by manual ground surveys, but this method is slow and expensive.

Standard versus Novel Aerial Photography

Aerial photographs of forests are normally acquired during the growing season under clear skies. Understorey conifers are difficult to see on such photos because:

- they can be obscured by overstorey trees;
- their crowns receive uneven illumination due to shadows cast by taller trees;
- their reflectivity is similar to the forest floor; and
- the forest floor is unevenly illuminated also due to tree shadows.

The latter three of these four problems are eliminated if aerial photographs are taken when snow covers the forest floor and the sky is overcast. Diffuse illumination from an overcast sky eliminates shadows and snow on the forest floor causing all canopy layers to appear as dark silhouettes against a light background. Where fir or spruce make up the live conifers, their visibility is further enhanced because their crowns tend to be denser than pine. The resulting photos are so different from aerial photographs taken under typical conditions that they can only be fully appreciated by direct comparison.

Figures 1a and 1b are aerial photographs of the same plot taken under two different sets of conditions in 2007. The site is a 126-year-old pine stand in a Sub-Boreal Pine–Spruce (SBPSxv) subzone southeast of Quesnel, B.C. Figure 1a shows the site in April when the ground is completely covered by snow and the sky was overcast. Figure 1b shows the site 1 month later on a clear day when the snow was gone. Three live understorey spruce trees are clearly visible in the left image, but not the right image. All of them are understorey spruce—the tree in the northeast corner had a measured top height of 10.7 m, while the pine overstorey was 15 to 18 m tall.

Photograph Acquisition and Processing

The purpose of this project is to test the ability to count and measure secondary structure in beetle-attacked pine stands using winter photographs. Methods used

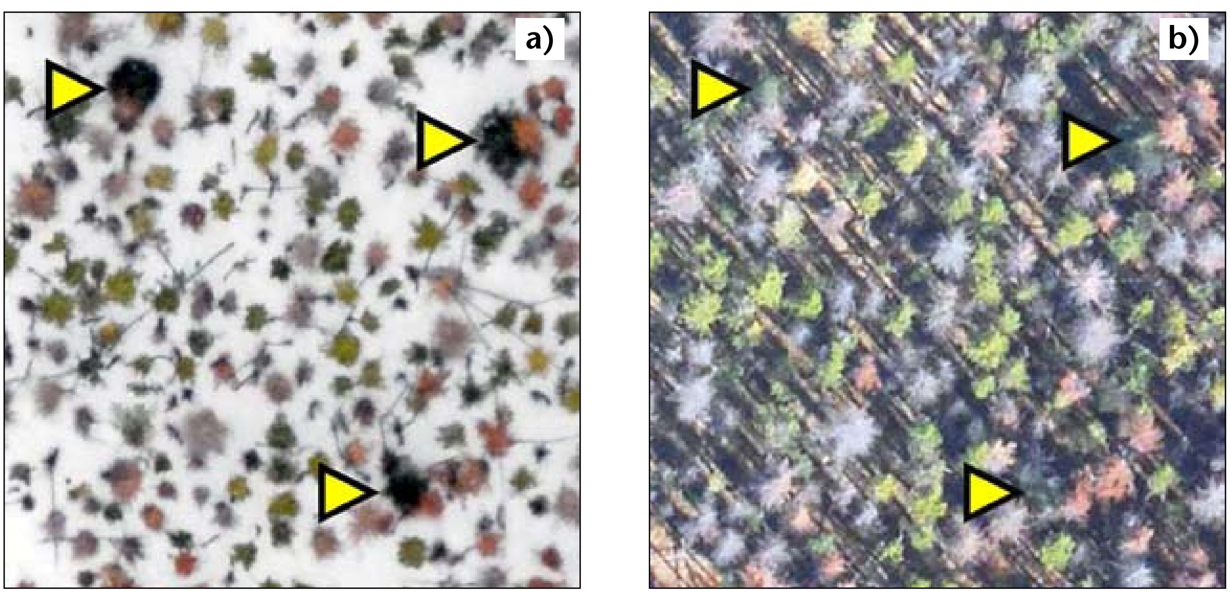

FIGURE 1. A 25 x 25 m plot in a lodgepole pine stand in April (a) and May (b). Arrows indicate understorey spruce trees.

for other purposes (e.g., operational) could differ, but complete snow cover and overcast skies are required to obtain imagery of this quality. Tree crowns should also be free of snow and frost. On the Fraser Plateau, we have found that the best conditions occur in late winter and early spring. Unfortunately, cloud bases are often 1000 m or less in late winter, thereby limiting aircraft altitude and the rate at which coverage can be obtained.

Equipment used for this project consists of two recreational GPS units, a consumer-grade digital single lens reflex camera (10.2 megapixel resolution), and a custom-made camera mount. A lens with a relatively narrow field of view (12.7° across the wide dimension) was used for most photography to minimize distortion and tree parallax. A Cessna aircraft was chartered and a technician navigated and operated the camera. Navigation to targets was done using the GPS. After each flight, approximate photo nadirs were calculated with GPS Photo Link software, which interpolated the location of the aircraft at the time each photograph was taken by using the time of image files and the GPS track data. The calculated photo nadirs were almost always within 100 m of the correct location. At a swath width of 200 m and ground speed of 185 km/hr, the potential spatial resolution was 5 cm, and the rate of coverage was 1 ha/sec.

Orthorectification and Stem Mapping

Since we are comparing stem maps and tree measurements made from aerial photographs with measurements made on the ground, we need to georeference photographs of our test plots. We do this using the following procedure.

- Original images are batch subsampled down to one-quarter of their original width using Thumbnailer software.
- Strip mosaics are created of target areas from subsampled images using PT GUI software.
- Strip mosaics are visually orthorectified to provincial orthophotos in Google Earth.
- Individual full-resolution images are visually rectified onto the subsampled strip mosaic in Google Earth.
- Stem maps and crown diameter measurements of secondary structure are created in Google Earth.

Other programs can also perform these tasks. This method does not correct projection errors due to lens distortion and sloping ground, but the narrow lens field of view and the gently sloping topography on our plots generally result in small horizontal projection errors. Errors associated with parallax shift of tree crowns on the provincial orthophotos are likely larger. Photographs that we orthorectify using the above method have estimated absolute position accuracies of several metres and relative accuracies of about 1%. During field-checking, the most important task is to correctly match trees on the photograph with trees on the ground. This is more easily done by interpreting photos on the ground than by precision surveying, so absolute accuracies of more than a few metres are unnecessary. It is relative accuracy rather than absolute accuracy that is important for stem mapping (i.e., horizontal scale and azimuth).

Orthorectification would not be necessary for some applications. As noted above, calculated photograph nadirs are generally within 100 m using this method. Image scale can be estimated from GPS-derived height above ground and the camera's angular field of view. This could provide sufficient spatial information for inventory overview purposes.

Conclusion

This variation on a simple remote-sensing technique provides a previously undocumented view of stand structure that is complementary to other remote sensing and sampling methods. Its rate of coverage and cost per unit area are orders of magnitude faster and cheaper than manual ground sampling. It could therefore help to address the current information gap concerning secondary structure in British Columbia's interior forests.

Acknowledgements

This project has been financially supported by Natural Resources Canada's Mountain Pine Beetle Program and by B.C. Ministry of Environment's Ecological Restoration Program.

References

Coates, K.D., C. DeLong, P.J. Burton, and D.L. Sachs. 2006. Abundance of secondary structure in lodgepole pine stands affected by the mountain pine beetle. Report for the Chief Forester.

Province of British Columbia. 2008. Order-in-Council No. 520. URL: *http://www.for.gov.bc.ca/hfp/silviculture/secondary_structure/Secondary%20Stand%20OIC.pdf*

Abstract

Regeneration beneath lodgepole pine-dominated stands attacked or threatened by the mountain pine beetle in the Kamloops Timber Supply Area, British Columbia

Alan Vyse[1]

Presentation Abstract

We established 512 plots to assess the species composition and abundance of germinants, seedlings, saplings, and larger trees in stands that have lodgepole pine as the leading species in the Kamloops Timber Supply Area located in south-central British Columbia. These stands have either been attacked or are threatened by the mountain pine beetle. The mean density of understorey stems varied widely within and between biogeoclimatic ecosystem classification subzones, but increased with increasing climatic moisture and elevation. Seedlings were the most abundant class of regeneration followed by saplings and poles. Subalpine fir (*Abies lasiocarpa* [Hook.] Nutt.) was the dominant regeneration species in 7 of 11 subzones. About half of all plots had more than 600 stems per hectare of acceptable regeneration. Germinants were infrequent except in the moist and high-elevation subzones. Species other than lodgepole pine were common in the canopy of sample stands, with the exception of the very dry cool Montane Spruce zone.

The abundant advance regeneration and presence of non-pine species in the canopy of many stands provides managers with flexibility in planning mountain pine beetle salvage operations. These stand components contribute to achieving both timber and non-timber objectives; however, subalpine fir is not highly regarded as a future timber species and protection of this species in future stand operations is a controversial issue. The low level of both stand components in the extensive dry Montane Spruce subzones creates challenges in designing plans for timber salvage or forest renewal.

KEYWORDS: *lodgepole pine, mountain pine beetle, regeneration, residual stand structure.*

Contact Information

1 2646 Valleyview Drive, Kamloops, BC V2C 4E5. Email: vyse@telus.net

Vyse, A. 2008. Regeneration beneath lodgepole pine-dominated stands attacked or threatened by the mountain pine beetle in the Kamloops Timber Supply Area, British Columbia. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):101. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Popular Summary

Mountain pine beetle and northern caribou: The Itcha-Ilgachuz experience

Harold Armleder[1] and Michaela Waterhouse[2]

Presentation Abstract

The purpose of the Itcha-Ilgachuz Research Project is to develop and test silvicultural systems that maintain caribou habitat, including terrestrial and arboreal forage lichens, while extracting timber. To develop a viable silvicultural system we are also researching regeneration (planted and natural), breeding birds, microclimate, long-term site productivity, treefall, and growth and yield.

We are also addressing the implications of high tree mortality, caused by mountain pine beetle (MPB), to caribou and other values. The current attack on the Chilcotin Plateau is causing much higher stand mortality than that experienced in the 1980s and a larger proportion of the landscape is affected. Irregular group shelterwood and group selection have been tested for over 10 years and results indicate these are viable silvicultural systems. With the arrival of MPB they remain a key part of the management approach. These systems have the potential to maintain habitat because: (1) the stand, even with mostly dead trees, still provides partial shade for lichens for about 20 years; (2) this gives regeneration a chance to grow for 20 years to provide future partial shade for lichens; (3) mobility is not an issue with 50% of the trees harvested; and (4) the standing dead trees provide a source of arboreal lichen fragments for the regenerating openings. Ongoing measurements will determine whether these initial indications are correct.

KEYWORDS: *Chilcotin, mountain pine beetle, northern caribou, partial cutting.*

Contact Information

1 B.C. Ministry of Forests and Range, Southern Interior Forest Region, 200–640 Borland Street, Williams Lake, BC V2G 4T1. Email: Harold.Armleder@gov.bc.ca

2 B.C. Ministry of Forests and Range, Southern Interior Forest Region, 200–640 Borland Street, Williams Lake, BC V2G 4T1. Email: Michaela.Waterhouse@gov.bc.ca

Armleder, H. and M. Waterhouse. 2008. Mountain pine beetle and northern caribou: The Itcha-Ilgachuz experience. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):102–105. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Summary

The Itcha-Ilgachuz herd of northern caribou is one of the largest in British Columbia. Together with the contiguous Rainbow Mountains and Charlotte Alplands herds these caribou occupy about 1.5 million ha of the west Chilcotin. Much of this range is within forest that is commercially harvested. The purpose of the Itcha-Ilgachuz Research Project is to develop and test silvicultural systems that maintain caribou habitat, including terrestrial and arboreal forage lichens, while extracting timber. To develop a viable silvicultural system, we are researching lichen response (Miège *et al.* 2001a, 2001b), planted (Waterhouse *et al.* 2001; Daintith *et al.* 2005) and natural regeneration (Steen *et al.* 2007), breeding birds (Waterhouse and Armleder 2007), microclimate (Sagar *et al.* 2005), long-term site productivity (Wei *et al.* 2000), treefall (Waterhouse and Armleder 2004), and growth and yield.

Results-to-date have highlighted the ecological uniqueness of the Itcha-Ilgachuz area of the west Chilcotin plateau. The Montane Spruce (MSxv) and Sub-Boreal Pine Spruce (SBPSxc) biogeoclimatic subzones located here have no analogues in British Columbia. The terrestrial lichen community, for example, is very rich (Miège *et al.* 2001a) and responds to timber harvesting in ways that are different than other parts of northern caribou range. Clearcutting dramatically reduces lichen abundance and quality (Miège *et al.* 2001b).

What is the future of the Itcha-Ilgachuz herd in the face of the current mountain pine beetle (MPB) outbreak as lodgepole pine is ubiquitous over the range of these caribou? A major concern is the effect of dead trees to the lichen communities that make up the bulk of their winter diet. Dead trees will become obstacles to accessing forage, fallen needles and boles will cover terrestrial lichens and remove arboreal lichens, and the microclimate (light, frost, temperature, moisture) will be modified. Increased light could stimulate vascular plant productivity to compete with terrestrial lichens. Other concerns include: the increased risk of catastrophic fire, the obstacles to movement (e.g., seasonal migrations and predator avoidance) that dead fallen trees may present in the future, the impact of massive areas of dead trees to the primary prey for wolves (i.e., moose, deer) and subsequent predation on caribou, and the impact of increased access as salvage-logging of beetle-killed trees proceeds.

Current and past research, as well as experience gained from a previous MPB outbreak in the mid-1980s, has led to the development of a management strategy to make the habitat as resilient as possible as the current MPB impacts unfold. The strategy includes several approaches over the 1.5 million ha range including:

- 52% in the conventional harvest land base,
- 31% in parks or no harvest areas,
- 13% in modified harvest areas, and
- 4% in a natural seral distribution zone (Youds *et al.* 2002).

The current MPB attack on the Chilcotin Plateau is causing much higher stand mortality than that experienced in the 1980s and a vastly larger proportion of the landscape is affected. Irregular group shelterwood and group selection have been tested for over 10 years and results indicate these are viable silvicultural systems (Daintith *et al.* 2005; Steen *et al.* 2007). With the arrival of MPB they remain a key part of the management approach on over 181 000 ha. These systems have the potential to maintain habitat because the stands, even with mostly dead trees, still provide partial shade for lichens (Figure 1). It is the sudden

FIGURE 1. With irregular group shelterwood (partial cutting that removes 50% of the stand area) the remaining trees, even if mostly dead, will continue to provide partial shade to lichens until regeneration can take over that role.

FIGURE 2. Aerial view of irregular group shelterwood and group selection removing 50% and 33% of the trees, respectively. Even after beetle-induced mortality, these silvicultural systems should maintain significant terrestrial lichen, facilitate animal movement after treefall, and reduce fire hazard.

exposure of lichen thalli to strong sunlight that causes mortality. The rate of treefall in this environment is slow so a gradual reduction in shade should occur over at least a 15–20 year period. This would give tree regeneration a chance to grow for one to two decades to provide future partial shade for lichens. Mobility should not be an issue with 50% of the trees harvested. Even if most of the remaining trees fall, the harvested openings will allow unobstructed travel through the stands. Additionally, the standing dead trees should provide a source of arboreal lichen fragments for the regenerating openings in the MSxv subzone. Ongoing measurements will determine whether these initial indications are correct.

At the same time, uncertainties exist. In 2006, about 50% of the trees over 12.5 cm DBH were dead from beetle attack on the trial blocks (M. Waterhouse, unpublished data). This number is higher now. With this much higher level of mortality, it is possible that treefall will be accelerated from our previous experience in the area. This would mean a shorter period of shading by standing trees; conversely, the fallen trees would also partially shade lichen. Uncertainty around the potential obstacle situation is focussed on the areas not harvested. The degree of concern will depend on the proportion and distribution on the landscape of stands with very high levels of mortality (e.g., > 80%). Mountain pine beetle surveys planned for 2008 will assess the situation now that the attack is largely complete.

Fire hazard is likely to be highest 15–20 years after attack when significant numbers of trees may have fallen and newly established young trees occupy the understorey (MacKenzie *et al*. 2007). Preventing massive wildfires is of prime importance. A plan to mitigate fire risk has been produced for Itcha-Ilgachuz Park, but implementation is uncertain (MacKenzie *et al*. 2007). In the areas of modified harvest, the partial cutting should reduce fire hazard by reducing fuel loading, providing fire breaks, and breaking the continuity of the overstorey (Figure 2).

Replicated research starting in the mid-1990s and about 1500 ha of adaptive management trials, plus long-term plots in unharvested forests, will help our understanding grow. This may lead to refinements of the approaches to manage caribou habitat in the future.

References

Daintith, N.M., M.J. Waterhouse, and H.M. Armleder. 2005. Seedling response following partial cutting in lodgepole pine forests on caribou winter range in west-central British Columbia. Forestry Chronicle 81:409–417.

MacKenzie, K., B. Gray, and B. Blackwell. 2007. Fire management plan: Itcha-Ilgachuz park. B.C. Ministry of Environment, Williams Lake, B.C. Unpublished Report.

Miège, D., T. Goward, H. Armleder, M. Waterhouse, and D. Burgess. 2001a. Impact of partial cutting on lichen diversity in lodgepole pine forests on the Chilcotin Plateau in British Columbia. B.C. Ministry of Forests, Research Branch, Victoria, B.C. Working Paper No. 55/2001.

Miège, D., H. Armleder, M. Waterhouse, and T. Goward. 2001b. A pilot study of silvicultural systems for northern caribou winter range: Lichen response. B.C. Ministry of Forests, Research Branch, Victoria, B.C. Working Paper No. 56/2001.

Sagar, R.M., M.J. Waterhouse, and B. Chapman. 2005. Microclimate studies in silvicultural systems on the Chilcotin Plateau of British Columbia: The Itcha-Ilgachuz project (1997–2003). B.C. Ministry of Forests, Research Branch, Victoria, B.C. Technical Report No. 22.

Steen, O.A., M.J. Waterhouse, H.M. Armleder, and N.M. Daintith. 2007. Natural regeneration of lodgepole pine following partial harvesting on northern caribou winter range in west-central British Columbia. BC Journal of Ecosystems and Management 8(1):61–74. URL: ***http://www.forrex.org/publications/jem/ISS39/vol8_no1_art5.pdf***

Waterhouse, M.J. and H.M. Armleder. 2004. Windthrow in partially cut lodgepole pine forests in west-central British Columbia. B.C. Ministry of Forests and Range, Research Branch, Victoria, B.C. Extension Note No. 70.

Waterhouse, M.J. and H.M. Armleder. 2007. Forest bird response to partial cutting in lodgepole pine forests on caribou winter range in west-central British Columbia. BC Journal of Ecosystems and Management 8(1):75–90. URL: ***http://www.forrex.org/publications/jem/ISS39/vol8_no1_art6.pdf***

Waterhouse, M.J., N. Daintith and O. Steen. 2001. Itcha-Ilgachuz Alternative Silvicultural Systems Project: Microclimate, planted stock and natural regeneration. B.C. Ministry of Forests, Research Section, Williams Lake, B.C. Extension Note No. 35.

Wei, X., W. Liu, M. Waterhouse, and H. Armleder. 2000. Simulations on impacts of different management strategies on long-term site productivity in lodgepole pine forests of the central interior of British Columbia. Forest Ecology and Management 133:217–229.

Youds, J., J. Young, H.M. Armleder, M. Folkema, M. Pelchat, R. Hoffos, C. Bauditz, and M. Lloyd. 2002. Cariboo Chilcotin land use plan: Northern caribou strategy. Cariboo Mid-coast Interagency Management Committee, Williams Lake, B.C. Special Report.

Popular Summary

Road access management: The US Forest Service approach

Patrick Daigle[1]

Presentation Abstract

We know that roads can alter habitat, increase wildlife mortality, disperse non-native plants and animals, lower site productivity, and affect wildlife migration patterns. Roads can also negatively affect soil conditions, water flow, and water and air quality. In some instances, roadsides improve native species' habitat. The British Columba Forest Service administers around 82 million ha of land and an estimated 400 000–550 000 km of roads. In many ways, the US Forest Service (US–FS) has similar challenges as it manages about 77 million ha and approximately 600 000 km of roads.

Managing roads and access requires the balancing of tradeoffs among costs and the uses and benefits provided by roads. The roads analysis process informs decisions about managing the US National Forest transportation system. US–FS roads are analyzed using best available scientific information, the contribution of existing and proposed roads to management objectives, and a process for balancing the social, economic, and environmental tradeoffs. The process includes six steps: setting up the analysis; describing the situation; identifying issues; assessing benefits, problems, and risks; describing opportunities and setting priorities; and reporting key findings. During analysis, US–FS staff respond to about 70 questions relating to environmental, social, and economic considerations. In addition, a four-cell road matrix is used during a risk assessment. The four cells are: High Value/Low Risk; High Value/High Risk; Low Value/Low Risk; and Low Value/High Risk. National Forest roads (or sections of roads) are put into one of the four cells. The results summarized in the matrix help guide investments in road management.

KEYWORDS: *access, roads, US Forest Service, wildlife.*

Contact Information

1 B.C. Ministry of Environment, PO Box 9338 Stn Prov Govt, Victoria, BC V8W 9M1.
Email: Patrick.Daigle@gov.bc.ca

Daigle, P. 2008. Road access management: The US Forest Service approach. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):106–110. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Introduction

Roads can alter habitat, increase wildlife mortality, disperse non-native plants and animals, lower site productivity, and at larger scales affect wildlife migration patterns. In addition, roads can negatively affect physical and chemical soil conditions, water flow, and water and air quality. In some instances, roadsides improve native species' habitat (Forman and Alexander 1998; Gucinski *et al*. 2001; Hamilton and Wilson 2001; Ferguson *et al*. 2002).

The BC Forest Service (BC–FS) administers around 82 million ha of land; those lands contain about 400 000–550 000 km of roads (Forest Practices Board 2005). Interestingly, the US Forest Service (US–FS) manages similar amounts: about 77 million ha of land (US–FS website) and approximately 600 000 km of roads (Bell 2000).

This paper describes:

- the road analysis process for the US–FS transportation system, which informs management decisions about maintenance, traffic management, road removal, and related concerns (US–FS 1999); and
- on-the-ground techniques for road maintenance, closure, stabilization, and removal (Moll 1996).

Illustrated examples of two US–FS road analyses are provided by Mitchell *et al*. (2003) and Schmitzer and Horsch (2001).

Land and resource managers in British Columbia can learn from the extensive work that went into designing the US–FS road analysis process. Road-related issues and human pressures are similar on both sides of the border.

Roads Analysis: Informing Decisions about Managing a Road System

In the US–FS, planning and managing road systems amounts to balancing tradeoffs—that is, costs against human uses and benefits. The costs are road-related effects to ecosystem values and resources (e.g., erosion, alien invasive species) and the dollar costs to maintain roads and mitigate environmental damages. The uses and benefits are those provided by access to US National Forests (US–FS 1999) and include access to timber, recreation, fire management, as well as numerous other benefits.

An interdisciplinary team (ID Team) analyzes roads on a national forest basis. These teams are made up of specialists involved in engineering, soils, recreation, wildlife, hydrology, timber, and geographic information systems. The national forest analyses cover areas from 400 and 800 thousand ha each. In some situations, the analysis may be limited to an examination of the "backbone" of the transportation system—those arterial (primary) and collector (secondary) roads that are the highest-traffic roads for public use with low-clearance vehicles and the most costly to maintain (Schmitzer and Horsch 2001; Mitchell *et al*. 2003).

Road analyses consider the following factors:

- the best available scientific information about the ecological effects of roads;
- the expense of maintaining, constructing, reconstructing, and decommissioning roads;
- social and economic costs and benefits; and
- how existing and proposed roads play a role in achieving land and resource management objectives.

Road analyses are conducted using the following six steps.

1. **Set up the analysis –** Analysis scale and scope, planning process, timeline, roles of ID Team participants and line officers.
2. **Describe the situation –** Maps, descriptions, land and resource plans, and other data.
3. **Identify issues –** Key road-related questions and issues (environmental, social, and economic) and their origins.
4. **Assess benefits, problems, and risks –** A systematic and extensive assessment of road-related uses and effects (environmental, social, economic) including potential for achieving land and resource objectives.
5. **Describe opportunities and set priorities –** A formulation of technical recommendations and rankings that addresses issues, challenges, benefits, and risks as well as options for modifying the road system to achieve land and resource objectives, using public participation where appropriate.
6. **Reporting the main findings –** Maps, data, assessment analyses, and narrative documentation of the road analysis and the opportunities identified.

The product of the road analysis includes:

- descriptions and maps portraying opportunities to improve the focus on future road requirements,
- environmental matters, and
- budgets.

The ID Team addresses about 70 questions relating to ecological, social, and economic considerations. The questions help the Team adapt its road analysis to its particular national forest. Questions are related to the considerations and examples listed in Table 1.

The Clearwater National Forest in northern Idaho used a decision matrix (Figure 1) during its road analysis (Mitchell *et al*. 2003). The matrix categorizes roads analyzed, gives guidance, helps portray a summary of management approaches, and establishes spending priorities. Information in the matrix is a guide, not a decision about future road management. Roads (or road portions) are put into one of the four boxes in the risk matrix.

The criteria applied to each road segment are: annual maintenance cost, recreation use value, access value, and resource management value. These are valued as high (3), medium (2), or low (1).

TABLE 1. Ecological, social, and economic considerations related to roads

Considerations	Examples
Ecological Function and Process	Alien species, insects, disease, disturbance regimes, noise
Aquatics, Riparian, Water	Hydrology, soil stability, water quality, pollutants, angling, poaching
Terrestrial Wildlife	Habitat, human presence in habitat, legal and illegal human activities
Economics	Agency costs/revenues for managing timber, minerals, range, water
Special Forest Products	Collection
Special-Use Permits	Concessionaires, utility sites, corridors
General Public Transport	Access to communities, in-holdings and easements, human safety
Administrative Use	Research, inventory, monitoring, investigation, enforcement
Protection	Fuels, wildfire, and dust management, firefighter and public safety
Recreation	Un-roaded and road-related recreation
Passive-Use Value	Unique natural features; cultural, sacred, and spiritual factors
Social Issues	Historical sites, traditional uses, social and economic health
Civil Rights	Effects on certain groups of people (minority, ethnic, disabled, etc.)

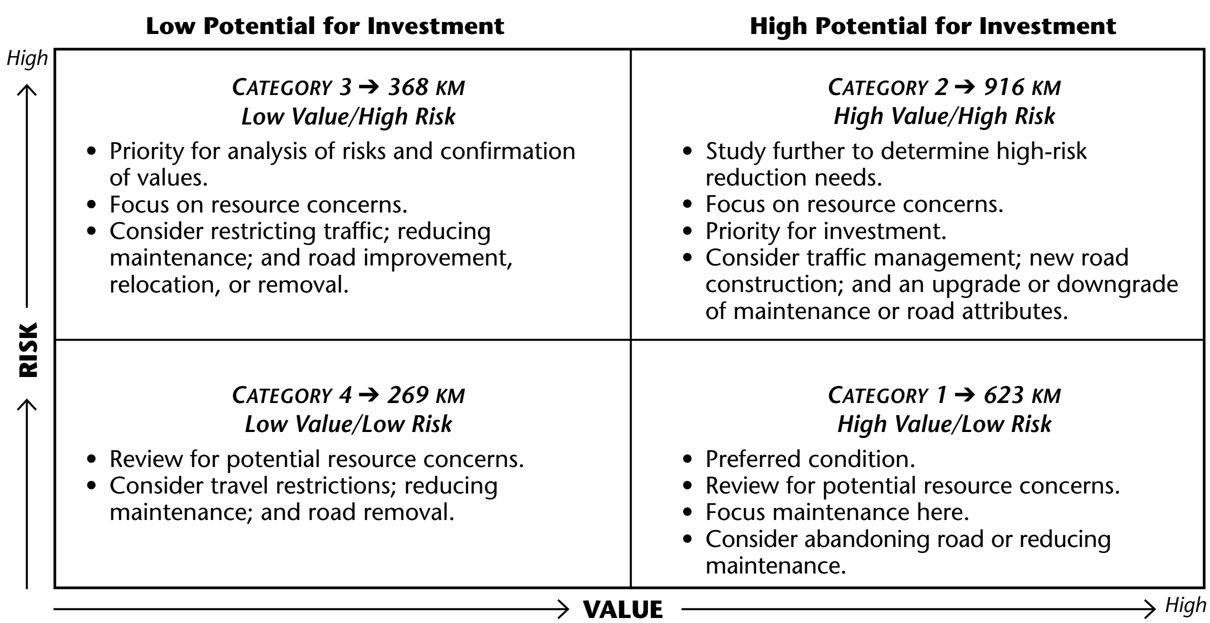

FIGURE 1. Road risk–value decision matrix (Mitchell *et al*. 2003).

Pertaining to each road segment, resource risk criteria are mass wasting risk, surface erosion risk, aquatic risk, and wildlife risk. Similarly, these criteria were tagged and assigned a value as high, medium, or low.

Products of a National Forest road analysis include:

- a report for US–FS managers, stakeholders, and the public detailing the analysis process, information considered, and opportunities and recommended priorities for future National Forest road systems;
- maps showing risks and prospects for each known road or segment in the system; and
- other maps and tables displaying priorities and changes in the road system.

Road Maintenance, Closure, Stabilization, and Removal Techniques

Moll (1996) provides guidance, approaches, techniques, and considerations for access management. The techniques relate to priorities and treatments for road closure and obliteration, management actions for areas adjacent to roads, and effectiveness monitoring.

The cost of traffic control and road maintenance and removal vary. Management actions aimed at arterial roads are relatively costly, those on collector roads are more moderate, and work on important local roads is relatively low cost.

Techniques that can be used to control access include:

- using on-site road blockage materials (e.g., berms, deep ditches, boulders)
- importing road blockage material (e.g., boulders)
- revegetating (especially with shrub species such as alder)
- building fences
- installing gates (seasonal or full-time), especially on new roads before public use patterns develop
- abandoning roads or road sections (if stable and overgrown)
- modifying the road prism (e.g., by de-compacting, outsloping, or reducing or eliminating road-induced changes to natural topography)
- removing the road (obliterating or decommissioning) at an appropriate level, such as:
  - re-contouring the road entrance
  - completing some work along the road to address mass failure and erosion
  - completing a substantial amount of work as per level 2 above
  - re-contouring most of road

Other considerations relating to access management techniques include:

- relocating portions of a road to more stable sites and removing old sections
- making good use of topsoil resources
- educating road users by providing reasons for closures (signs may be used for this)
- promoting research and monitoring to assess the effectiveness of the management techniques in pursuit of continuous improvement
- for areas adjacent to roads, altering flood flows by constructing wetlands or building "silt traps"
- for gully control, building check dams, installing armour, vegetating, or using a combination of techniques may be useful

Land and resource managers in British Columbia can learn a lot from the thinking that has gone into the US–FS road analysis process—it's systematic and thorough (US–FS 1999). The national forest analyses mentioned here clearly demonstrate the process steps and products coming from the ID Team reports (Schmitzer and Horsch 2001; Mitchell *et al.* 2003). In addition, on-the-ground techniques described by Moll (1996) can help agency and industry managers, staff, and machinery operators.

References

Bell, J. 2000. The [US] National Forest Road System. *In* Proceedings: Watershed Management and Operations Management. M. Flug, D. Frevert, and D.W. Watkins (editiors). American Society of Civil Engineers, Reston, Va.

Ferguson, A., M. McPhee, B. Janowich, and H. Utzig. 2002. Forest access and terrestrial ecosystems. Prepared for the B.C. Ministry of Water, Land and Air Protection, Victoria, B.C.

Forest Practices Board. 2005. Access management in British Columbia: Issues and opportunities. Victoria, B.C. Special Report No. 23. URL: *http://www.fpb.gov.bc.ca/special/reports/SR23/SR23.pdf*

Forman, R. and L. Alexander. 1998. Roads and their major ecological effects. Annual Review of Ecology, Evolution, and Systematics 29:207–231.

Gucinski, H., M.J. Furniss, R.R. Ziemer, and M.H. Brookes (editors). 2001. Forest roads: A synthesis of scientific information. U.S. Department of Agriculture Forest Service, Pacific Northwest Research Station, Portland, Oreg. General Technical Report PNW-GTR-509. URL: ***http://www.fs.fed.us/pnw/pubs/gtr509.pdf***

Hamilton, D. and S. Wilson. 2001. Access management in British Columbia: A provincial overview. Prepared for the B.C. Ministry of Water, Land and Air Protection, Victoria, B.C.

Mitchell, C., D. Annis, A. Connor, D. Davis, D. Jones, R. Kusicko, J. Mital, P. Murphy, N. Schluessler, and S. White. 2003. Roads analysis report. US–FS Clearwater National Forest (Idaho). URL: ***http://www.fs.fed.us/r1/clearwater/rap/table_contents.pdf***

Moll, J. 1996. A guide to road closure in the [US] Forest Service. U.S. Department of Agriculture Forest Service, Technology and Development Program, San Dimas, Calif. URL: ***http://www.fs.fed.us/eng/pubs/pdfimage/96771205.pdf***

Schmitzer, R. and L. Horsch. 2001. Roads analysis report. US–FS Medicine Bow National Forest (Wyoming). URL: ***http://www.fs.fed.us/r2/mbr/projects/roads/adobepdf/medbow/mbnf_rds_analysis_final.pdf***

United States Forest Service. 1999. Roads analysis: Informing decisions about managing the [US] National Forest Transportation System. US–FS Miscellaneous Report No. FS-643. URL: ***http://www.fs.fed.us/eng/road_mgt/DOCSroad-analysis.shtml***

Popular Summary

Development of a decision-support framework for conservation planning in the British Columbia Interior

Pierre Iachetti[1]

Presentation Abstract

The current mountain pine beetle outbreak in British Columbia presents a major challenge to planners and policy-makers. They are asked to integrate multiple information sources, show transparency in the decision-making process, and publicly evaluate tradeoffs. Fully informed land use and resource management decisions would need to integrate information about the ecology of ecosystem disturbance, the role of climate and climate change, the effects of forest harvesting, the values and environmental services that forest ecosystems provide to human society, and the relationships between human communities and forests. The Nature Conservancy of Canada (NCC) and partners are developing a decision-support system that incorporates scenario development, in which several conflicting or alternative scenarios are used to explore the uncertainty of the future consequences of a decision, to aid decision making. This also provides a platform for engaging stakeholders who have divergent viewpoints and competing objectives. In its Mountain Pine Beetle Action Plan, the British Columbia government has recognized that identifying conservation areas to protect the region's biodiversity is a high priority. The tools for identifying specific areas for protecting and restoring biodiversity are well developed and are used worldwide to support major decisions about the use of land and water. However, conservation planning approaches tend to focus primarily on the scientific component, without much consideration of the socio-economic and political aspects that are key to implementing conservation strategies. The Nature Conservancy of Canada's BC Interior Project incorporates socio-economic considerations (e.g., the value of ecosystem services) as well as climate change implications into the conservation planning process to create more realistic conservation scenarios.

KEYWORDS: *conservation planning, decision support, mountain pine beetle, Nature Conservancy of Canada.*

Contact Information

1 Director of Conservation Science and Planning, Nature Conservancy of Canada, 300–1205 Broad Street, Victoria, BC V8W 2A4. Email: pierre.iachetti@natureconservancy.ca

Iachetti, P. 2008. Development of a decision-support framework for conservation planning in the British Columbia Interior. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):111–114. URL: *http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf*

Introduction

The current mountain pine beetle outbreak in British Columbia presents a major challenge to scientists, planners, and policy-makers. They are asked to integrate multiple information sources, show transparency in the decision-making process, and publicly evaluate tradeoffs. Fully informed land use and resource management decisions would need to integrate information about the ecology of ecosystem disturbance, the role of climate and climate change, the effects of forest harvesting, the values and environmental services that forest ecosystems provide to human society, and the relationships between human communities and forests (Kimmins *et al.* 2005). As well, decision makers need to be able to effectively evaluate the consequences of alternative management scenarios.

An integrated approach to land use and resource management planning recognizes that a successful strategy must meet multiple objectives through a variety of means. Integrated planning and new governance models are increasingly seen as critical in addressing complex land use and resource management issues. How different groups and jurisdictions work together (how they share information, conduct planning, understand and identify interests and responsibilities, etc.), is often as important as the scientific information that they use to support decision making. Conventional approaches of integrating and applying knowledge are not adequate to examine the complex and highly variable ecological and socio-economic issues that influence land use and resource management decisions and the effects they have on landscapes (Berry *et al.* 1996).

In the case of the mountain pine beetle outbreak, sustainable land use and resource management planning is even more difficult because much of the ecological information is changing, making it very difficult to effectively apply this information to decision making. Technological developments have opened up possibilities for managing and analyzing information and assessing future scenarios. In turn, improved data integration and modelling capabilities provide an opportunity to support new and innovative governance models. These can improve integration and collaboration in planning and in implementing effective land use and resource management decisions (A. Tautz, pers. comm.).

The Nature Conservancy of Canada (NCC), along with collaborators from provincial government, academia, federal agencies, First Nations, and non-governmental organizations, is developing a decision-support system that incorporates computer models, ecological information, valuation of ecosystem services, climate change, mountain pine beetle impacts, and scenario development, in which conflicting or alternative scenarios are used to explore the uncertainty of the future consequences of a decision. Decision-support systems (DSS) can be used in further interactions between management and science when developing adaptive management strategies and also provide a platform for engaging stakeholders who have divergent viewpoints and competing objectives (Tremblay *et al.* 2004).

Decision-support Systems

Managers often experience information overload. They may also perceive scientific messages as promoting a particular viewpoint that is driven by undue self-interest; they know they cannot trust all information sources equally, and contradictory information makes it harder for managers to assess the risk of embracing or ignoring a particular message. To managers, scientific information can be useful, but only if it is packaged to be unambiguous, is not excessively complex, and is compatible with existing planning models (Roux *et al.* 2006).

One way for researchers to support sustainable land use and resource management planning is to develop tools for exploring and making effective decisions using an ecosystem-based management approach. Computer-based decision-support tools provide information by means of forecasting models and access to geographical information systems (GIS) and databases. These can be used by decision makers who are dealing with complex and unstructured or semi-structured management issues. Decision-support systems are a collection of conceptual, methodological, and computer-based tools (Cain 2001), which can be used to structure a decision process by making data easily accessible and allowing "what-if" analyses of possible decisions to be made. Although it will not resolve uncertainty, developing potential future scenarios is a useful way of improving decision making and stakeholder involvement in situations of high uncertainty (Lebel *et al.* 2005).

Methods and Design

Through our experience in developing previous conservation plans and basic decision-support tools, and taking into consideration the technical issues, data gaps, and uncertainties inherent in the planning and decision-making process, we are developing the DSS using the following general criteria.

- Use reserve-selection models to develop conservation plans.
- Use more than one reserve-selection tool to compare results.
- Incorporate socio-economic as well as ecological information.
- Incorporate spatial and temporal dynamics into analyses and tools.
- Involve as many relevant stakeholders as is feasible.
- Conduct user-needs assessments to understand the types of decisions and information needs that a decision-support system can support.
- Incorporate different types of information from various sources.
- The proposed framework and decision-support system is one piece of a land and resource management framework.

No consistent means exist for evaluating success in conveying knowledge. However, two features of a decision-support system can facilitate this: transparency and the ability to "game." We facilitate transparency when we can readily display and modify the workings of the system. Those using or exploring the tool can easily call-up graphic displays of relationships and the data used to form them. The ability to "game," or evaluate alternative management scenarios and underlying relationships, benefits from transparency and also from model efficiency and convenient displays of outputs, including the ability to easily contrast scenarios (Bunnell and Boyland 2003).

Scenarios

Scenario development is a potential framework for conservation planning and policy-making in an uncertain and changing world. Scenarios are developed to consider various possible futures that include many of the important uncertainties in a system, rather than focussing on a single outcome. Scenarios are useful for encouraging systematic planning in situations of uncertainty or for revealing a range of dynamic processes and causal chains that lead to alternative outcomes. Developing scenarios is a fundamental prerequisite of strategic planning. Although the virtues of scenario planning have long been appreciated in business and other fields, it has not been used widely in ecology or conservation (Bohensky *et al.* 2006).

Having interest groups participate in the process can build a shared understanding and generate conservation decisions that may be more readily adopted by stakeholders (Siitonen 2003). In scenario development, we use a holistic, integrated, and participatory approach to help us understand the intrinsic heterogeneity and uncertainty of ecosystem management. We begin by determining a set of key questions or issues in consultation with stakeholders. We then assess the current state of the system and identify alternative pathways that the system might take. The key questions often revolve around uncertainties or unknowns in the system. The next step is to build projections of these questions into the future, which can be done qualitatively or quantitatively. The scenario development process involves the following steps (Lebel *et al.* 2005).

- deciding on the purpose of scenario and stakeholder involvement
- getting people to think about the long-term future;
- introducing the concept of scenarios
- backcasting
- identifying the main areas of uncertainty
- developing focal questions to be addressed by scenarios
- identifying the main drivers of change
- developing a first set of scenarios
- deciding on modelling capacity
- modelling runs
- critically assessing scenarios and incorporating model results
- identifying important surprises
- identifying the implications of scenarios for the main stakeholders
- deciding on final scenarios
- evaluating the implications of each scenario for addressing identified uncertainties
- incorporating wider stakeholder feedback and scenario iterations, and reporting on the scenarios and their implications

Conclusions

To help us evaluate conservation scenarios in the British Columbia Interior during conservation planning, we need a decision-support system that integrates knowledge from across many disciplines and data in different forms. The latter includes spatial and tabular databases, the results of mathematical models, spatial analyses, and expert opinions.

The decision-support system outlined here is data-driven and requires spatially referenced biological and socio-economic information, as well as scenarios of future environmental change. In reality, conservation planners and decision makers need to go beyond available spatial data and consider expert opinion, as well as many intangibles related to socio-political feasibility, indirect benefits, and conservation opportunities, such as willing sellers.

Ultimately, good conservation decisions rest on the decision makers' experience and sound judgement; however, that judgement still depends on scientific data and information on the known geography of resource quality, threat, and conservation costs. The decision-support system should organize and render information in the way that is most useful to the decision-making process (Davis *et al.* 2006).

Conservation biology is increasingly called upon to help define and achieve sustainable visions of the future. Although scenarios offer a promising mechanism, the tools for the task need to be honed. Through the use of scenarios, scientists, planners, and decision makers can collectively embrace uncertainty, prepare for a range of potential futures, and turn would-be crises into opportunities for positive change (Bohensky *et al.* 2006).

References

Berry, M.W., R.O. Flamm, B.C. Hazen, and R.L. MacIntyre. 1996. The Land-Use Change Analysis System (LUCAS) for evaluating landscape management decisions. Department of Computer Science, University of Tennessee, Knoxville, Tenn. URL: ***http://www.cs.utk.edu/~lucas/publications/ieee/ieee.html***

Bohensky, E.L., B. Reyers, and A.S. VanJaarsveld. 2006. Future ecosystem services in a southern African river basin: A scenario planning approach to uncertainty. Conservation Biology 20:1051–1061.

Bunnell, F.L. and M. Boyland. 2003. Decision-support systems: It's the question not the model. Journal for Nature Conservation 10:269–279.

Cain, J. 2001. Planning improvements in natural resources management: Guidelines for using Bayesian networks to support the planning and management of development programmes in the water sector and beyond. Centre for Ecology and Hydrology, Crowmarsh Gifford, Wallingford, Oxon, UK.

Davis, F.W., C. Costello, and D. Stoms. 2006. Efficient conservation in a utility-maximization framework. Ecology and Society 11:33. URL: ***http://www.ecologyandsociety.org/vol11/iss31/art33/***

Kimmins, J.P., B. Seely, C. Welham, and A. Zhong. 2005. Possible forest futures: Balancing biological and social risks in mountain pine beetle epidemics. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, B.C.

Lebel, L., P. Thongbai, K. Kok, J.B.R. Agard, E. Bennett, R. Biggs, M. Ferreira, C. Filer, Y. Gokhale, W. Mala, C. Rumsey, S.J. Velarde, and M. Zurek. 2005. Sub-global scenarios. *In* Millennium ecosystem assessment, ecosystems and human well-being: Multiscale assessments, findings of the Sub-Global Assessments Working Group. D. Capistrano, C. Samper, M. J. Lee, and C. Raudsepp-Hearne (editors). Island Press, Washington, D.C.

Roux, D.J., K.H. Rogers, H.C. Biggs, P.J. Ashton, and A. Sergeant. 2006. Bridging the science–management divide: Moving from unidirectional knowledge transfer to knowledge interfacing and sharing. Ecology and Society 11:4. URL: ***http://www.ecologyandsociety.org/vol11/iss11/art14/***

Siitonen, P. 2003. Reserve network design in fragmented forest landscapes. Department of Ecology and Systematics, Division of Population Biology. University of Helsinki, Helsinki, Finland.

Tremblay, J.-P., A. Hester, J. Mcleod, and J. Huot. 2004. Choice and development of decision support tools for the sustainable management of deer-forest systems. Forest Ecology and Management 191:1–16.

Trends in salvage-logging practices in mountain pine beetle-affected landscapes: Implications to biodiversity conservation

Doug Lewis[1], Christian St Pierre[2], and Alistair McCrone[3]

Presentation Abstract

The current mountain pine beetle (MPB) outbreak is unprecedented in size affecting over 10 million ha of mature pine forest in British Columbia. The outbreak has led to accelerated salvage harvesting in an attempt to recover timber affected by the MPB. Although British Columbia's *Forest and Range Practices Act* (*FRPA*) states clear objectives to maintain biodiversity, few legal provisions exist to maintain structural legacies in logged openings or to regulate the size of logged areas and adjacency to existing cutover areas during salvage logging of MPB-infested stands. Improper planning of forest retention could result in adjacent blocks joining to create large "aggregate" cutover areas with a paucity of residual forest structure.

We monitored trends in the number, size, and total area of "aggregate openings" and internal forest retention in three salvage-logged landscapes in southern British Columbia. We used forest cover information and satellite ortho-imagery to identify openings and forested retention at discrete time periods before and during extensive salvage logging of MPB-affected forests. Salvage logging has resulted in a rapid increase in the amount of logged area and size of openings. Internal forest retention is generally low, consisting mainly of small openings (< 5 ha on average) with most less than 1 ha and 1–5 ha in size. Lack of retained forest structure in salvaged areas may present a significant risk if we increasingly rely on these areas to conserve biodiversity over time on landscapes subject to pressures from future natural disturbances and logging.

KEYWORDS: *biodiversity conservation, mountain pine beetle, salvage logging, stand-level retention.*

Contact Information

1 B.C. Ministry of Environment, 1259 Dalhousie Drive, Kamloops, BC V2C 5Z5.
Email: Doug.W.Lewis@gov.bc.ca

2 B.C. Ministry of Environment, 1259 Dalhousie Drive, Kamloops, BC V2C 5Z5.
Email: Cstpierre@gov.bc.ca

3 B.C. Ministry of Environment, 1259 Dalhousie Drive, Kamloops, BC V2C 5Z5.
Email: Alistair.Mccrone@gov.bc.ca

Lewis, D., C. St Pierre, and A. McCrone. 2008. Trends in salvage-logging practices in mountain pine beetle-affected landscapes: Implications to biodiversity conservation. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):115–119. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Introduction

Conserving biodiversity and protecting habitat for wildlife in British Columbia is a clear social expectation reinforced within forest management legislation and land use planning processes. On the timber harvesting land base, British Columbia's *Forest and Range Practices Act* (FRPA) employs strategies such as wildlife tree patches (WTPs) and Old-growth Management Areas (OGMAs) to designate forest reserve areas that will maintain forest structure for long periods. Additional constraints on harvesting mature timber adjacent to "non-greened up" regenerating cutblocks and size of logged openings are used to distribute the effects of forest harvest on the land base over space and time. Exceptions to these legislated constraints apply during salvage logging following natural disturbances,[1] however. In addition, no legal provisions exist that require increased levels of residual forest structure in large salvage-logged openings.

Significant concerns have been raised about the lack of existing legislated measures to mitigate potential negative effects to wildlife habitat and biodiversity during extensive salvage logging of forests affected by the mountain pine beetle (MPB) (Eng 2004; Snetsinger 2005). Where the rate of harvest is spatially and temporally accelerated (as is the case with salvage of MPB-affected stands), few forest management options exist outside of retention of mature forest structural attributes (e.g., standing live and dead trees, downed wood) during harvest to maintain wildlife habitat and biodiversity (Franklin *et al.* 1997). Some guidance has been provided on increased forest retention based on the size of "aggregate openings" within the landscape context (Eng 2004; Snetsinger 2005; Klenner 2006); however, this guidance is not legally binding. It relies on forest professionals to exercise professional judgement in ensuring that forest retention is consistent with wildlife habitat and biodiversity objectives.

The goal of this project was to evaluate trends in the amount and size of retained forest patches in logged openings by monitoring trends in stand-level retention practices. Our analysis focussed on four landscape units (Skull, Swakum, Pennask, and Tranquille) in the Southern Interior of British Columbia. Our analysis of salvage-logged MPB areas predates the Chief Forester's direction of December 2005 (Snetsinger 2005). It therefore provides a benchmark against which to compare the suggested levels of mature forest retention. However, updated ortho-imagery (2007) in the Pennask Landscape Unit allowed us to monitor retention levels since the Chief Forester's guidance was introduced and to determine, on a limited scale, the changes in stand-level retention practices following this guidance.

Methods

Using an ArcGIS 8.0\9.0 platform, we compiled the most recent satellite imagery available. This consisted of 2004–2005 orthophoto mosaics and 2007 orthophotos with 1–m pixel resolution. Using Vegetation Resources Inventory (VRI) data, we identified all cutblocks within a landscape unit cut since 1975.[2] We considered aggregates of cutblocks that were immediately adjacent to one another and logged within 30 years of one another as a single "opening." We digitized the outer boundaries of each of these openings so that they were considered as a single polygon in the analysis. Where slivers of residual forested areas separated adjacent blocks (i.e., a riparian reserve corridor), we considered these as a single "opening" if the width of the residual area was less than 50% of its length; in this case, the sliver was counted as a "retained area," otherwise these were counted as separate openings.

We digitized all residual forest patches within openings as "retained patches" down to a size of approximately 0.02 ha (10 × 20 m), but did not consider areas of dispersed retention in the analysis.[3] We assumed that all forest area within an aggregate opening was retained if it was entirely surrounded by harvested area or if the length of the forested area extended into the opening at least twice the length of its base (Andison 2004; Heinrich and Lewis 2005). This approach should capture the majority of deliberate forest retention.

To describe the proportion of total harvested area in retained forest patches as well as the size and number

[1] See the Forest Planning and Practices Regulation (B.C. Reg. 14/2004): *http://www.for.gov.bc.ca/tasb/legsregs/frpa/frparegs/forplanprac/fppr.htm*

[2] 1975 was used as an arbitrary cutoff date because many openings before this date were selectively cut or data was not reliable on harvest dates.

[3] Retained patches were considered clumps or aggregates of individual trees with no discernable difference to surrounding unlogged forest; dispersed retention includes areas where individual trees are retained within a harvested area. The inclusion of areas of dispersed retention in the analysis is reviewed in the discussion section.

TABLE 1. Opening size classes and recommended retention amounts

Opening size class	Opening size (ha)	Recommended harvest area retention (%)
1	0–50	10
2	50–250	10–15
3	250–1000	15–25
4	1000+	25+

TABLE 2. Retained patch size classes

Retained patch size class	Range (ha)
1	0–1
2	1–5
3	5–15
4	15–35
5	35+

of retained patches relative to the size of harvested openings, we computed the following statistics.

- The total area of retained forest patches within a cutblock or opening relative to the opening size. We used four openings sizes consistent with Eng (2004), Snetsinger (2005), and Klenner (2006) (see Table 1).
- The size distribution of retained patches relative to opening size classes. Retained patches were grouped into five size classes (Table 2) consistent with other methodologies used to assess residual forest remnants following natural disturbance (Andison 2004; Heinrich and Lewis 2005).
- The average number of retained patches in each retention patch size class relative to opening size.

Results and Discussion

Amount and Size of Forest Retention Patches

The amount of area retained in forested patches in all opening size classes as of 2005 was below levels recommended in the Chief Forester guidance document of December 2005 (Figure 1). Average levels ranged between landscape units. For example, for openings greater than 1000 ha, retention amounts in the Tranquille Landscape Unit exceeded 25%; the other three landscapes had between 10% and 15% retention resulting in an average of 17% for all landscape units combined. When all landscape units were combined, 75% of openings under 50 ha had no internal retention; most openings under 250 ha had low retention levels (< 5% internal forest retention) and few internal retention patches (< 5 on average), which were generally small in size (< 1 ha and 1–5 ha) (Figure 2). A low number of retained patches in openings of this size is consistent with results from other monitoring studies that showed low levels of internal stand retention and that most (> 70%) of retention was associated with wildlife tree patches external to the cutblock (B.C. Ministry of Forests and Range 2007). Our results suggest that as opening sizes increase to 250–1000 ha and greater than 1000 ha, the number of internal forest retention patches increases, but the size of retention patches is still generally small with the majority (> 80%) under 5 ha (Figure 3).

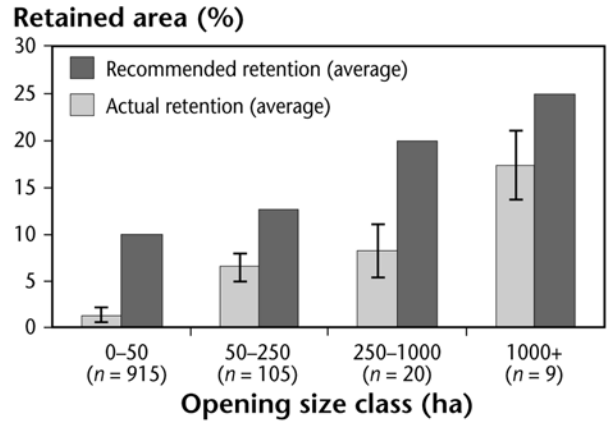

FIGURE 1. Average area of retained forest patches by opening size class in four landscape units. Error bars show one stand error about the mean.

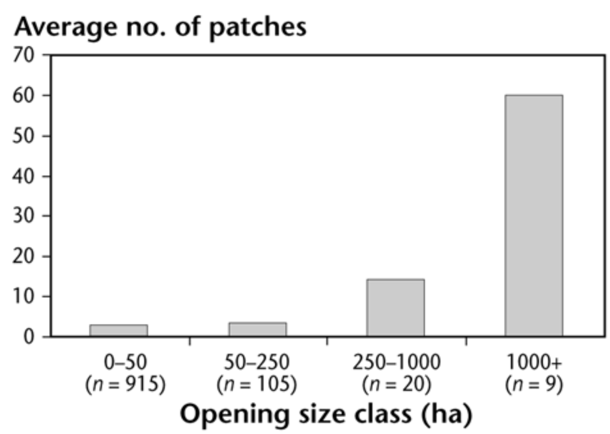

FIGURE 2. Average number of retained forest patches by opening size class in four landscape units.

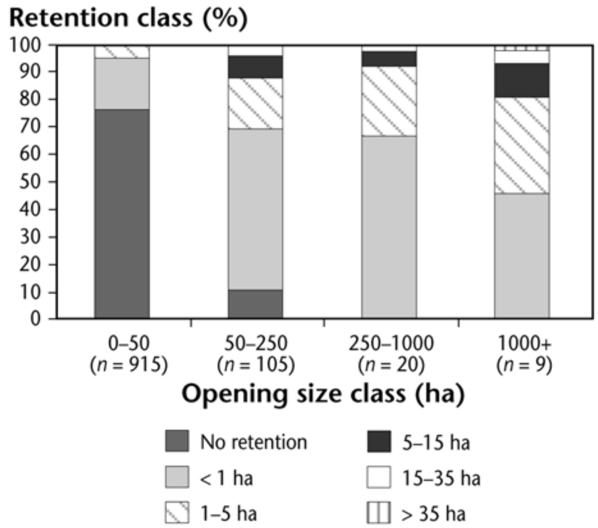

FIGURE 3. The proportion of all retained patches in each retention patch size class by opening size class.

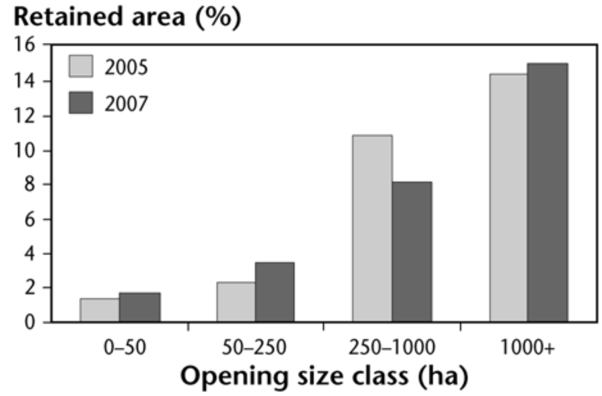

FIGURE 5. Change in percent area retained by opening size class from 2005 to 2007 in the Pennask Landscape Unit.

Trends in Retention Practices from 2005–2007: Pennask Landscape Unit

In the Pennask Landscape Unit, the amount of retained forest area in different-sized openings increased relative to 2005 retention amounts (Figure 4). Despite this increase, the overall amount of forested retention in the landscape unit remained below recommended levels and changed little relative to 2005 (Figure 5). Openings logged between 2005 and 2007 in the 250–1000 ha size class aggregated to create openings greater than 1000 ha and resulted in increased retention in the 1000+ ha openings size class; retention amounts in the 250–1000 ha class declined (Figure 5).

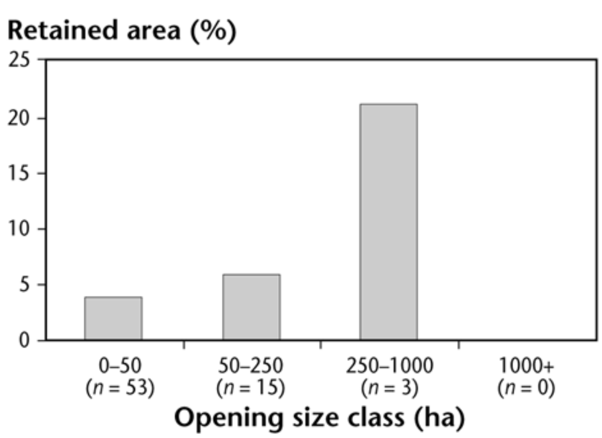

FIGURE 4. Percent retained area by opening size class for openings salvage-logged between 2005 and 2007 in the Pennask Landscape Unit.

Management Implications

Low levels of stand-level forest retention are a concern. As salvage harvesting of MPB-affected forests continues and salvage openings become aggregated across the landscape, fewer options are available to retain forest, potentially resulting in large cutover areas with few retained forest areas. Achieving habitat and biodiversity management objectives will require that adequate area is retained during MPB salvage. To ensure this, planning by individual forest licensees, or coalitions of licensees where multiple volume-based tenures overlap, is required to increase both the size and amount of retained patches proportional to the size of logged openings. Large retained patches in heavily cutover areas will be important refugia for many wildlife and plant species allowing organisms to persist following harvest and re-colonize as the forest regenerates (Franklin *et al.* 2002; Lindenmayer *et al.* 2008). A range of different-sized, well-distributed patches will also create spatial heterogeneity within the stand, and increase vertical structure, complexity, and future coarse woody debris in the regenerating forest (Klenner 2006). The risk of negatively affecting wildlife habitat and biodiversity is relatively low in the initial phases of salvage operations because the land base influenced by salvage and openings sizes is small. As the amount of area salvaged increases and individual cutblocks aggregate in large contiguous openings, the potential risk of negatively affecting biodiversity and impairing ecosystem processes can increase. This risk may be further exacerbated when the remaining mature forest is available for harvest in 20–30 years before logged areas recover sufficiently to provide habitat, or when future natural disturbances occur that further reduce the supply of mature forests.

So how much stand-level retention is enough? We agree that retention amounts outlined by the Chief Forester (Snetsinger 2005) represent an average target to be achieved for logged openings of similar size. This stance recognizes that actual retention amounts will vary around this average depending on forest composition, landscape, and habitat features. However, the Chief Forester states that: "the retention considered appropriate will be dependant on assessments and professional judgement." Thus, professionals must consider the various non-timber values present within a stand and landscape, the risks associated with MPB salvage harvesting, and the strategies to mitigate these risks when establishing appropriate levels for stand-level retention during salvage harvesting. Landscape context is a key factor in this consideration: landscapes with a high proportion of cumulative salvage will pose a greater risk to biodiversity because a sufficient balance of landscape retention augmented by stand-level retention is required to allow populations of forest-dependent species to persist and ecosystem processes to function (Klenner 2006).

References

Andison, D.W. 2004. Island remnants on foothills and mountain landscapes of Alberta. Part II – Residuals. Foothills Model Forest, Hinton, Alta. Alberta Foothills Disturbance Ecology Research Series Report No. 6.

B.C. Ministry of Forests and Range. 2007. Stand-level biodiversity monitoring in 44 large cutblocks in the Central Interior of British Columbia. Forest Practices Branch, Victoria, B.C. FREP Series No. 010. URL: ***http://www.for.gov.bc.ca/hfp/frep/publications/index.htm***

Bunnell, F.L., K.A. Squires. and I. Houde. 2004. Evaluating the effects of large-scale salvage logging for mountain pine beetle on terrestrial and aquatic vertebrates. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, B.C. Mountain Pine Beetle Initiative Working Paper 2004-2.

Eng, M. 2004. Forest stewardship in the context of large-scale salvage operations: An interpretation paper. B.C. Ministry of Forests, Victoria B.C., Technical Report No. 019. URL: ***http://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr019.htm***

Franklin, J.F., D.R. Berg, D.A. Thornburgh, and J.C. Tappeiner. 1997. Alternative silvicultural approaches to timber harvesting: Variable retention harvest systems. *In* Creating a forestry for the 21st century. K.A. Kohm and J.F. Franklin (editors). Island Press, Washington, D.C. pp. 111–139.

Franklin, J.F., T.A. Spies, R. Van Pelt, A.B. Carey, D.A. Thornburgh, D.R. Berg, D.B. Lindenmayer, M.E. Harmon, W.S. Keeton, D.C. Shaw, K. Bible, and J. Chen. 2002. Disturbances and structural development of natural forest ecosystems with silvicultural implications, using Douglas-fir forests as an example. Forest Ecology and Management 155:399–423.

Heinrich, R. and D. Lewis. 2005. Analysis of residual forest structure left following wildfires within the Natural Disturbance Type (NDT) 3 in the Southern Interior of British Columbia: A preliminary review. Draft Report to Weyerhaeuser Canada, Kamloops, B.C.

Klenner, W. 2006. Retention strategies to maintain habitat structure and wildlife diversity during the salvage harvesting of mountain pine beetle attack areas in the Southern Interior Forest Region. B.C. Ministry of Forests and Range, Southern Interior Forest Region, Kamloops, B.C. Forest Science Extension Program Note No. 04.

Lindenmayer, D.B., D.R. Foster, J.F. Franklin, M.L. Hunter, R.F. Noss, F.A. Schmiegelow, and D. Perry. 2004. Enhanced salvage harvesting policies after natural disturbance. Science 303(5662):1303.

Lindemayer, D.B., P.J. Burton, and J.F. Franklin. 2008. Salvage logging and its ecological consequences. Island Press, Washington D.C.

Snetsinger, J. 2005. Guidance on landscape- and stand-level structural retention in large-scale mountain pine beetle salvage operations. December, 2005. URL: ***http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/stewardship/cf_retention_guidance_dec2005.pdf***

Abstract

After the mountain pine beetle epidemic in interior British Columbia: Approaches to biodiversity maintenance and forest conservation

Kathy Martin[1], Mark Drever[2], and Andrea R. Norris[3]

Presentation Abstract

The forests in the Interior of British Columbia support a wide array of vertebrates, including more than 200 bird species, for which the current mountain pine beetle (MPB) epidemic has radically changed their habitats. We used data collected from 1995 to 2007 on abundance and nesting of birds at 27 sites around Williams Lake, B.C., to characterize avian responses to the epidemic, and to recommend reliable indicators and forest management practices that may safeguard biodiversity following the MPB epidemic and subsequent salvage operations. The epidemic has had the strongest effects on birds that forage on insects found in the bark of trees, and has served as a resource pulse of heightened, but ephemeral, availability of insect prey. Several small-bodied insectivorous bird species have exhibited "boom and bust" population dynamics and are now very low, whereas others such as woodpeckers continue to increase in abundance as the epidemic progresses. The abundance and diversity of woodpeckers are reliable indicators of forest birds in general, such that forest management practices amenable to maintaining woodpeckers may serve to safeguard forest biodiversity. In particular, harvest practices that retain all the deciduous component and large coniferous trees will best meet biodiversity maintenance and conservation goals in post-epidemic forests. We suggest these structures act as biological legacies that can speed ecosystem recovery to a state within its normal range of variability.

KEYWORDS: *biological legacy, harvest, mixedwood forest, woodpecker.*

Contact Information

1 Environment Canada, Delta, B.C., and Centre for Applied Conservation Research, University of British Columbia, 2424 Main Mall, Vancouver, BC V6T 1Z4. Email: kmartin@interchange.ubc.ca

2 Centre for Applied Conservation Research, University of British Columbia, 2424 Main Mall, Vancouver, BC V6T 1Z4. Email: mark.drever@ubc.ca

3 Centre for Applied Conservation Research, University of British Columbia, 2424 Main Mall, Vancouver, BC V6T 1Z4. Email: arnorris@interchange.ubc.ca

Martin, K., M. Drever, and A.R. Norris. 2008. After the mountain pine beetle epidemic in interior British Columbia: Approaches to biodiversity maintenance and forest conservation. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):120. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Popular Summary

Potential implications of beetle-related timber salvage on the integrity of caribou winter range

R. Scott McNay[1], Randy Sulyma[2], Joan Voller[3], and Viktor Brumovsky[4]

Presentation Abstract

Habitat supply modelling was used to forecast the likely effects of timber salvage related to mountain pine beetle (*Dendroctonus ponderosae*) on the integrity of critical habitat used by threatened herds of woodland caribou (*Rangifer tarandus caribou*). We simulated mountain pine beetle attack and four different timber harvest options from current conditions over 90 years into the future to compare the relative supply of timber and winter range within landscapes used by caribou. The management options assessed included: (1) a base case mimicking current era constraints on industrial forest development, including general wildlife measures undertaken within winter ranges, no special significance of the mountain pine beetle epidemic, and timber was harvested if it met merchantability standards; (2) a scenario in which licensees preferred salvage of pine (*Pinus contorta*) over other timber as long as there was no significant development of infrastructure and winter ranges were specifically avoided; (3) a scenario similar to the previous one, but with harvest constraints in winter ranges temporarily suspended; and (4) a scenario similar to the previous, but with an increase in allowable annual cut. The results of these management scenarios were tabulated, compared, and the implications on timber and habitat for caribou discussed. The comparisons potentially guide salvage of timber killed by mountain pine beetle and help raise significant issues concerning conservation of winter range for woodland caribou.

KEYWORDS: *mountain pine beetle, north-central British Columbia, timber salvage, ungulate winter range, woodland caribou.*

Contact Information

1 Wildlife Infometrics Inc., 3–220 Mackenzie Boulevard, Mackenzie, BC V0J 2C0.
Email: scott.mcnay@wildlifeinfometrics.com

2 Wildlife Infometrics Inc., 3–220 Mackenzie Boulevard, Mackenzie, BC V0J 2C0.
Email: randy.sulyma@wildlifeinfometrics.com

3 Wildlife Infometrics Inc., 3–220 Mackenzie Boulevard, Mackenzie, BC V0J 2C0.
Email: joan.voller@wildlifeinfometrics.com

4 Wildlife Infometrics Inc., 3–220 Mackenzie Boulevard, Mackenzie, BC V0J 2C0.
Email: viktor.brumovsky@wildlifeinfometrics.com

***JEM* — VOLUME 9, NUMBER 3** *Published by FORREX Forum for Research and Extension in Natural Resources*

McNay, R.S., R. Sulyma, J. Voller, and V. Brumovsky. 2008. Potential implications of beetle-related timber salvage on the integrity of caribou winter range. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):121–126.
URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Introduction

Managing woodland caribou habitat, in light of the mountain pine beetle (MPB) outbreak, is bound by much uncertainty (Cichowski 2007; Whittaker and Wiensczyk 2007) surrounding the response of understorey vegetation, predator–prey relationships, the connectedness of seasonal ranges, and the risk that caribou must undergo in moving among seasonal ranges. Complicating the situation further is the forest management response to mitigate the outbreak, which could include changes to forest policy (B.C. Ministry of Forests and Range 2005).

Our goal was to reveal potential implications of different forest management options on the integrity of caribou winter range. Broad areas of ungulate winter ranges (UWRs) will undoubtedly be affected by salvage of MPB-killed timber, but to what extent and for how long? Our specific objectives were to help provide information about:

- the potential influence of the MPB outbreak on woodland caribou UWRs;
- timber salvage options that would optimize quality of UWRs and recovery of MPB-killed timber; and
- the potential need for review of UWR management direction.

Methods

We used results from simulated MPB disturbance (Walton *et al.* 2007) and hypothetical forest management options using the Spatially Explicit Landscape Event Simulator (SELES; Fall and Fall 2001) to forecast spatially explicit characterizations of the landscape from 2007 to 2100. These conditions were assessed using the Caribou Habitat Assessment and Supply Estimator (McNay *et al.* 2006) to identify effects on UWR values. Model runs were applied in recovery plan areas for three herds of woodland caribou (the Chase, Scott, and Wolverine herds) extending over 3.2 million ha in north-central British Columbia (McNay *et al.* 2008). We constructed sets of forest management options that, to the extent possible, represented real choices in determining the most efficient salvage of MPB-killed timber. A natural disturbance scenario provided a baseline reference.

The following four management scenarios were undertaken:

1. base forest management intended to mimic legislated UWR policy;
2. salvage by exploiting existing infrastructure emphasizing salvage of dead pine provided less than 1 km of new road was needed;
3. enhanced pine salvage emphasizing salvage by increasing the amount of access roads that could be built to a maximum of 30 km and allowing harvest in UWRs; and
4. enforced pine salvage with and allowable annual cut uplift.

Results

Supply of Ungulate Winter Range

The abundance of quality UWR was maintained in the short-term (next 5 years) regardless of the scenario applied. Scenario 1 maintained the most favourable UWR results for the Chase and Scott herds, and Scenario 2 provided the best results for the Wolverine herd (Figure 1). For the Chase and Wolverine herds, the amount of UWR began to decline significantly around 4 years from present and continued to decline throughout the salvage period and into the post-salvage period (after 2021). The abundance of UWR was maintained above the natural disturbance benchmark for the Chase and Scott herds regardless of the scenario applied. However, for the Chase herd, all scenarios approached the benchmark by 2040. The aggressive salvage scenarios (i.e., 3 and 4) resulted in a reduction of UWR for the Wolverine herd below the natural disturbance benchmark and this level was predicted to remain for the following 15 years.

When risk of predation and forage characteristics were considered in the assessment of UWR, the amount of quality range declined sharply from current conditions for all scenarios. For the Chase and Wolverine herds, the amount of UWR declined and then remained below the amount expected under natural disturbance (Figure 1). When predation risk was assessed, the variation among scenario results was apparently lower than when it was not considered.

Timber Supply

With the exception of Scenario 4, timber harvest was generally consistent (Figure 2). All scenarios, except Scenario 1, were successful at maintaining a high proportion of pine in the harvest (Figure 2). For all scenarios, the downward trend of the annual volume of timber harvested started at about 2017, declining significantly after 2015, and continued declining until 2070.

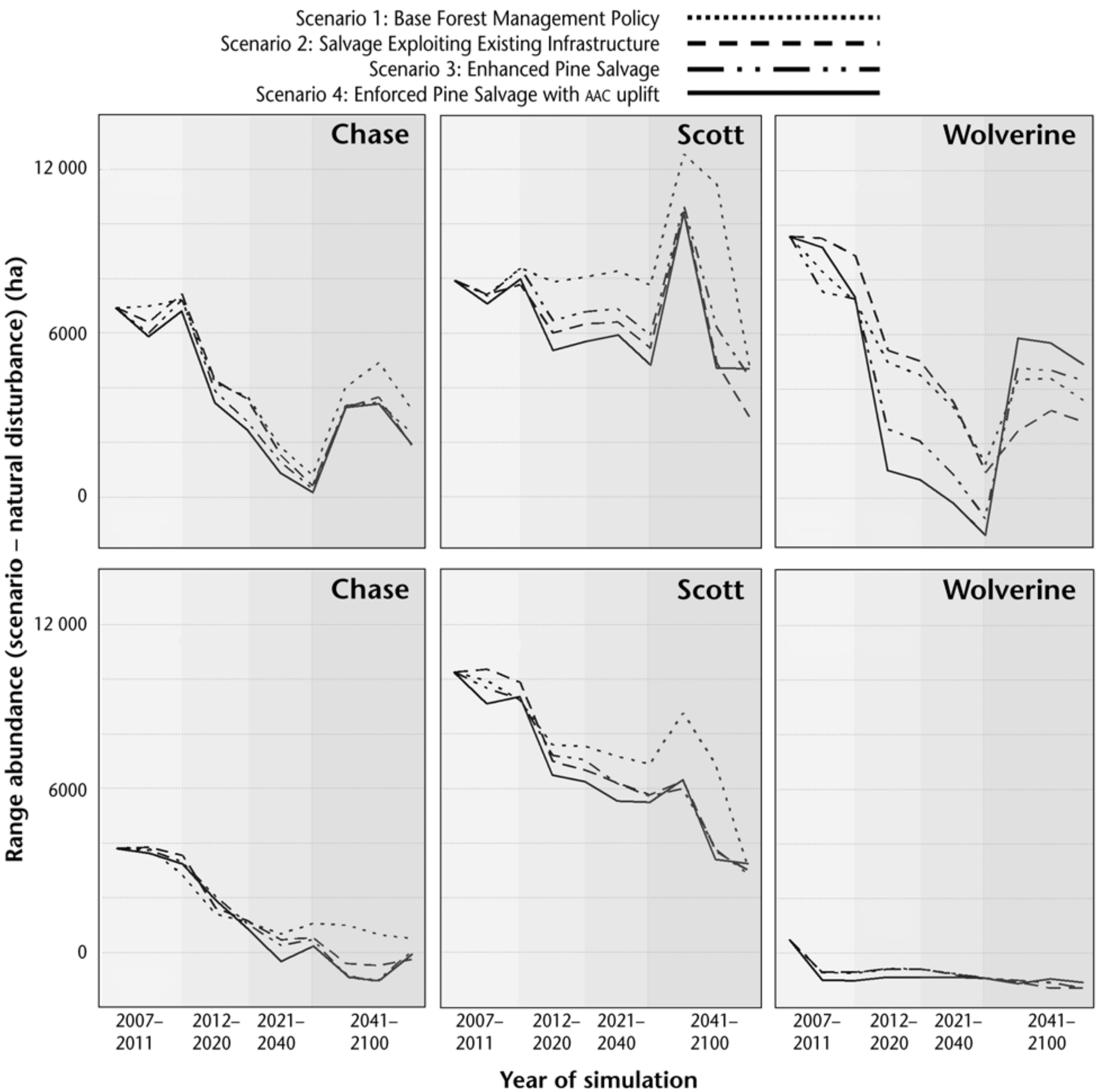

FIGURE 1. Simulation results (year 2007–2100) for management scenarios depicting the likely effects of salvaging timber killed by mountain pine beetles on the supply (range abundance) of modelled winter range used by woodland caribou herds (Chase, Scott, and Wolverine) in north-central British Columbia. Modelled range was based on areas of quality forage (top graphs) and areas of quality forage that were also free from predation risk (bottom graphs)

During the salvage period, the increase in harvest across the scenarios did not have a large influence on the amount of UWR; yet, on average, 40% more pine was recovered annually in Scenario 4 as compared to Scenario 1 (Figure 3). Conversely, the UWR constraints of Scenario 1 resulted in the lowest average annual harvest volume. In the post-salvage period, however, Scenario 1 maintained more UWR on average than the other scenarios, although the longer-term wood supply was relatively unaffected (Figure 3).

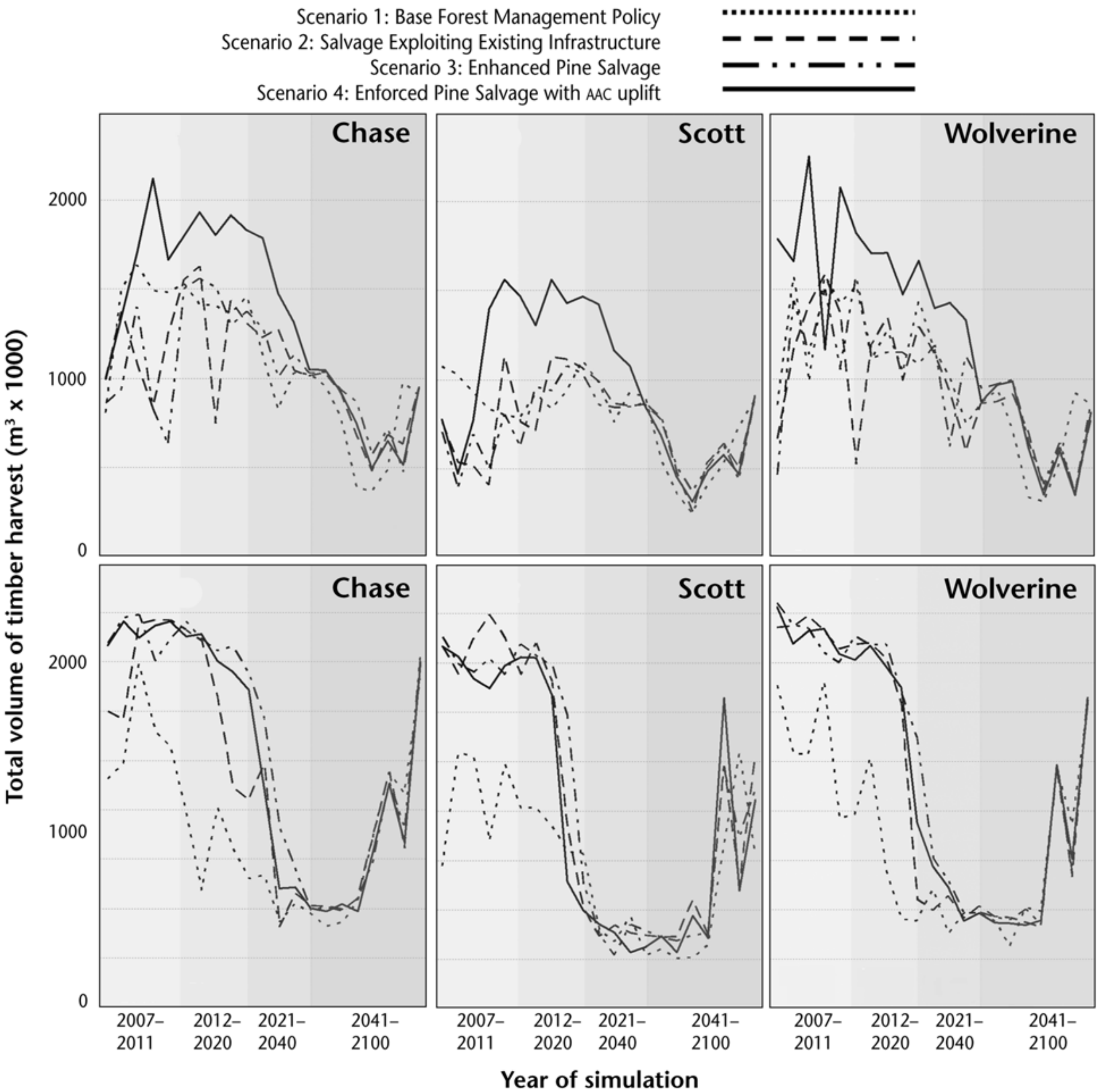

FIGURE 2. Simulation results (year 2007–2100) for management scenarios depicting the likely effects of salvaging timber killed by mountain pine beetles on the supply of timber (top graphs) and the amount of pine harvested (bottom graphs) within the range of woodland caribou herds (Chase, Scott, and Wolverine) in north-central British Columbia.

Discussion

The age distribution of pine-lichen forests within the study area was known to be skewed to stands between 70–140 years of age (B.C. Ministry of Forests 2001), implying the occurrence of widespread natural disturbances before the turn of the last century. The implication was an abundance of favourable conditions for UWR relative to the supply that can be sustained. Decline in the abundance of UWR was therefore inevitable and this was evident before consideration of the MPB outbreak (McNay *et al.* 2008). Although the natural disturbance benchmark is a useful construct (Delong and Tanner 1996; Fowler and Hobbs 2002), the apparent historic disturbance in our study areas reminds us that because of their associated level of uncertainty future forecasts should be used with caution.

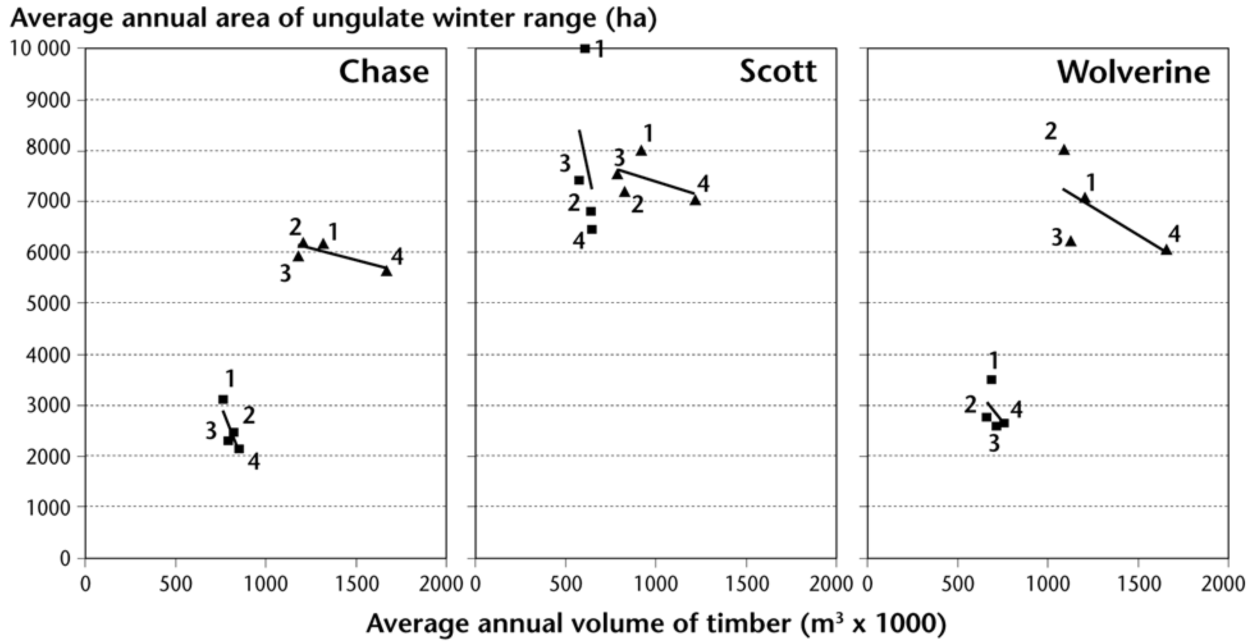

FIGURE 3. Simulation results (▲ salvage period year 2007–2020, ■ post-salvage period year 2021 to 2100) for management scenarios depicting the likely effects of salvaging timber killed by mountain pine beetles on the supply (range abundance) of modelled winter range available to herds of woodland caribou (Chase, Scott, and Wolverine) in north-central British Columbia.

Much of the pattern evident in the simulation results can be anticipated from the rules characterizing the scenarios (i.e., the models followed the scenario rules as expected). Although we attempted to construct scenarios that would diverge in results, in general we did not observe the expected variance. The disturbance intensity created by the MPB outbreak and the associated salvage logging caused an immediate reduction in UWR even when harvest of UWR was avoided. Even so, all timber supply trends converged indicating that none of the scenarios were likely to allow for the complete harvest of beetle-attacked pine. The reduction in timber supply in the latter part of the salvage period appeared to be influenced more by the degradation of wood quality than the availability of it. If wood quality was not an issue, volumes for Scenarios 1–3 should have remained higher than for Scenario 4 during the post-salvage period. Increased allowable harvest, when focussed on pine, seemed to be justified because the timber supply appeared related primarily to fibre availability.

Supply of UWR oscillated at a level of risk beyond which most habitat managers would be comfortable. Furthermore, inclusion of predation effects indicated that UWR will fall below the natural disturbance benchmark. Even when the abundance of suitable UWR rebounded in the long term, predation risk apparently remained high. Original plans for UWRs involved two management zones:

- a zone managed for terrestrial forage lichens, and
- a larger buffer area managed to minimize predation risk.

However, most UWRs were implemented without this buffer. The relative lack of difference among the simulation results when predation risk was considered indicated the lack of buffer areas was significant.

Counterintuitively, avoidance of UWRs by licensees (Scenario 2) is anticipated to result in a stronger deficit of the range in the long term and emphasizes the need for regular management of UWRs. Direct comparisons between supply of range and timber among the four scenarios support the notion that there were obvious tradeoffs to consider. Low variation among the UWR results in the short term indicate that the development of additional strategies could be implemented to maximize the benefit to wood fibre production. In the longer term, developing a management scenario with a lack of consideration for quality range appeared to produce poorer range conditions than strategies designed to maintain range values.

Research and Management Recommendations

The tactical management of UWRs (Scenario 1) and relaxation of harvest restrictions in certain UWRs (Scenario 3) may promote the maintenance of UWR in the long run and promote greater liquidation of MPB-killed trees. Since none of the simulated scenarios were able to harvest all MPB-killed pine, we recommend strategic selection of areas adjacent to UWRs that should not be harvested in the short term (i.e., defacto buffer areas to reduce predation risk). Also, strategic selection of harvest areas within UWRs will provide opportunities for recruitment of new UWR and help reduce the anticipated longer-term deficit in UWR supply. Selection of protected UWR should focus on areas where terrestrial lichens are judged to be the climax, rather than successional, vegetation structure. These sites tend to be relatively less productive for timber growth. By comparison, disturbance zones could be focussed where MPB attack is judged to lead to future decreases in snow interception or to accumulations of dead timber that will restrict caribou movement. These sites tend to be relatively more productive for timber growth. Alternative strategies that involve complete lack of disturbance in UWRs other than by the MPB (e.g., Scenario 2) are not likely to support the establishment of relatively stable UWR supply. If UWR is avoided, government will need to find methods to ensure the restoration of range conditions.

Acknowledgements

Thanks to L. Hulstein, S. Kuzio, A. Fall, and R. McCann. Funding was received from the British Columbia Forest Investment Account–Forest Science Program.

References

British Columbia Ministry of Forests. 2001. Timber supply review Mackenzie timber supply area analysis report. Timber Supply Branch, Victoria, B.C.

B.C. Ministry of Forests and Range. 2005. TFL 53 AAC increased in response to beetle infestation. URL: *http://www2.news.gov.bc.ca/news_releases_2005-2009/2005for0102-000947.htm*

Cichowski, D.B. 2007. Literature review: Effects of mountain pine beetles on caribou. Alberta Sustainable Resource Development, Edmonton, Alta.

Delong, C. and D. Tanner. 1996. Managing the pattern of forest harvest: Lessons from wildfire. Biodiversity and Conservation 5:1191–1205.

Fall, A. and J. Fall. 2001. A domain-specific language for models of landscape dynamics. Ecological Modelling 141:1–18.

Fowler, C.W. and L. Hobbs. 2002. Limits to natural variation: Implications for systemic management. Animal Biodiversity and Conservation 25(2):7–45.

McNay, S., D. Heard, R. Sulyma, and R. Ellis. 2008. A recovery action plan for northern caribou herds in north-central British Columbia. FORREX Forest Research Extension Partnership, Kamloops, B.C. FORREX Series No. 22. URL: *http://www.forrex.org/publications/forrexseries/fs22.pdf*

McNay, R.S., B.G. Marcot, V. Brumovsky, and R. Ellis. 2006. A Bayesian approach to evaluating habitat for woodland caribou in north-central British-Columbia. Canadian Journal of Forest Research 36:3117–3133.

Walton, A., J. Hughes, M.A. Eng, A. Fall, T. Shore, B. Riel, and P. Hall. 2007. Provincial-level projections of the current mountain pine beetle outbreak: Update of the infestation projection based on the 2006 provincial aerial overview of forest health and revisions to the "model" (BCMPB v4). B.C. Ministry of Forests and Range, Victoria, B.C.

Whittaker, C. and A. Wiensczyk. 2007. Caribou response to mountain pine beetle management: An expert workshop in Prince George, B.C. April 26, 2007. FORREX, Kamloops B.C.

Abstract

Ecosystem services in an uncertain world

Don G. Morgan[1], Andrew Fall[2],and Rob McCann[3]

Presentation Abstract

The forests of British Columbia are undergoing a transformation, shifting from a state where a steady supply of forest resources could be expected to one with extreme disturbance events, such as large mountain pine beetle (MPB) outbreaks and rapid increases of Dothistroma needle blight. These events disrupt the flow of valued ecosystem services (e.g., timber and wildlife habitat) that society depends on to provide economic benefit, ecosystem health, and human well-being. Conventional approaches to resource management assume a relatively constant supply of timber and wildlife habitat. However, the province's current MPB outbreak has undermined the viability of assuming consistency in the supply of these ecosystem services.

Some aspects of the supply of ecosystem services are known through empirical studies, such as the rate of growth of trees under certain ecological parameters. This knowledge can be used to extrapolate what may happen in the future for an ecosystem service under a given set of circumstances. However, the potential range and variability in plausible future conditions is uncertain. Based in ecological resilience theory, scenario planning has emerged as a methodology to explore this uncertainty.

This poster provides an overview of resilience theory and presents a case study of its application to an area experiencing an unprecedented MPB outbreak in southeastern British Columbia. By merging together the steps of scenario planning with a collaborative process to engage scientists, decision makers, and concerned citizens, resource management policies can be developed that enhance the resilience of ecosystem services to future uncertainty.

KEYWORDS: *ecosystem services, mountain pine beetle, scenario planning, timber supply, wildlife.*

Contact Information

1 B.C. Ministry of Forests and Range, Research Branch, Bag 6000, Smithers, BC V0J 2N0. Email: don.morgan@gov.bc.ca

2 Gowlland Technologies, 220 Old Mossy Road, Victoria, BC V9E 2A3. Email: andrew@gowlland.ca

3 Contractor, PO Box 421, Mackenzie, BC V0J 2C0. Email: rmccann@interchange.ubc.ca

Morgan, D.G., A. Fall, and R. McCann. 2008. Ecosystem services in an uncertain world. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):127. URL: *http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf*

Abstract

Mountain pine beetle and wildlife habitat supply

Don G. Morgan[1], Robert S. McNay[2], and Glenn Sutherland[3]

Presentation Abstract

Central British Columbia is experiencing an unprecedented mountain pine beetle (*Dendroctonus ponderosae*; MPB) outbreak. Changes in forest pattern and structure, resulting from the current MPB outbreak and timber-salvaging activities, could alter the structure and availability of wildlife habitat for those species whose range overlaps the outbreak area making more habitat for some species and a loss of habitat for others.

A pressing need exists for forest managers to determine appropriate strategies to enhance, as best as possible, the adaptive capacity of wildlife populations to the current MPB outbreak, particularly those that will potentially be adversely impacted. Information is required on which areas are appropriate for forest-salvaging activities and road building and which are not, and on where stand tending can lead to an accelerated recruitment of good wildlife habitat. However, numerous uncertainties are associated with this issue. For example, what will be the structural composition of the landscape after the MPB outbreak?

The goals of our project are to identify those wildlife species that will benefit and those that will be most adversely impacted by the current MPB outbreak and to identify forest and land management strategies that may enhance species resilience to the changes in landscape condition. This poster provides an overview of the project's three central components: (1) examples of wildlife species that may benefit and those that will be not; (2) methods for generating habitat maps and habitat occupancy; and (3) a habitat supply modelling framework.

KEYWORDS: *habitat supply, mountain pine beetle, species distribution, wildlife.*

Contact Information

1 B.C. Ministry of Forests and Range, Research Branch, Bag 6000, Smithers, BC V0J 2N0. Email: don.morgan@gov.bc.ca

2 Wildlife Infometrics, PO Box 308, Mackenzie, BC V0J 2C0. Email: scott.mcnay@wildlifeinfometrics.com

3 Cortex Consultants, 2a–1218 Langley Street, Victoria, BC V8W 1W2. Email: gsutherland@cortex.ca

Morgan, D.G., R.S. McNay, and G. Sutherland. 2008. Mountain pine beetle and wildlife habitat supply. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):128. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Popular Summary

Implications of forest management in response to the 1970s mountain pine beetle infestation on grizzly bears in the Flathead Drainage

Robin Munro[1], Bruce McLellan[2], and Clayton Apps[3]

Presentation Abstract

Although the extent of British Columbia's current mountain pine beetle (MPB) outbreak is unprecedented in history, it is not the first to have occurred in in the province. In the 1970s, the MPB outbreak in the East Kootenay Region, and in particular the relatively wide Flathead Valley, was one of the most significant infestations to have occurred in British Columbia. Many of the dead and dying pines in this valley were either left unharvested or salvage-logged. Our study investigated the response by grizzly bears to the development of the valley for salvage logging across several spatial scales. We used DNA "hair-snagging" methods to compare the effects of salvage-logged and unharvested areas on the distribution and abundance of grizzly bears. The influence of stand age class and road density on grizzly bear habitat selection was also quantified across multiple spatial scales using 30 years of radio telemetry data on 119 grizzly bears. The ecological and physical attributes of sites used by grizzly bears in mature pine stands and salvage-logged areas was also determined. Finally, we examined changes in the grizzly bear population's vital rates by decade. The rapid and extensive forest harvesting that is occurring in many regions of the province may have significant implications for other members of the ecological community as the ecosystem responds over the next several decades.

KEYWORDS: *grizzly bears, habitat selection, microsite selection, mountain pine beetle, population distribution, population dynamics, salvage logging.*

Contact Information

1 B.C. Ministry of Environment, 4051–18th Avenue, Prince George, BC V2N 1B3. Email: Robin.Munro@gov.bc.ca

2 B.C. Ministry of Forests and Range, PO Box 9158, Revelstoke, BC V0E 3K0. Email: Bruce.Mclellan@gov.bc.ca

3 Aspen Wildlife Research Inc., 2708 Cochrane Road NW, Calgary, AB T2M 4H9. Email: clayton.apps@telus.net

Munro, R., B. McLellan, and C. Apps. 2008. Implications of forest management in response to the 1970s mountain pine beetle infestation on grizzly bears in the Flathead Drainage. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):129–132. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Introduction

Mountain pine beetles (MPB) have attacked a significant portion of the lodgepole pine trees in British Columbia and many of these trees are dying. Because lodgepole pine usually grows in a relative monoculture after wildfire, trees in forests over large tracks of land will die. Foresters are faced with various options for salvage logging and post-harvest silviculture. The consequence of the dead trees and rapid and extensive forest harvesting will have significant implications for other members of the ecological community. In many portions of the area where pine are dying, grizzly bears are high-profile species that may be affected by forest industry decisions.

Although the extent of the current mountain pine beetle outbreak is unprecedented in history, it is not the first one. In the late 1970s, a MPB infestation occurred in the Flathead Valley in southeastern British Columbia and adjacent Montana (Figure 1). It was part of a larger outbreak that occurred across southwestern Alberta, the northwestern United States, the East Kootenays, and the Caribou region of British Columbia. This was one of the largest infestations to have occurred in both Canada and the United States (Young 1988). In the Flathead drainage, many entire valleys of predominantly lodgepole pine were attacked killing most of the pine. As a result, the dead pine was either left unharvested or salvage-logged, with salvage logging often being followed by replanting. With decisions regarding the management of the current situation needed immediately, an obvious question is "what can we learn from the past to guide us now?"

For several reasons, the Flathead Valley in southeastern British Columbia is uniquely suited to address this question. First, it is a very wide valley that was dominated with lodgepole pine after fires in the 1920s and 1930s. The width of the valley more closely mimics broader plateau terrain than other drainages, which are relatively narrow causing the epidemic to be more fragmented by high mountains and forest unsusceptible to the beetle. Second, the Flathead valley is divided by the Canada/United States border enabling the study area to be stratified into two treatment zones: north of the border, where lodgepole pines were salvage-harvested and south of the border, in Glacier National Park, where the pine beetle infestation was left totally unmanaged. Finally, there has been 30 years of continuous monitoring of the grizzly bear population in the valley. These characteristics make this area a potentially valuable study site to rapidly review what has happened over the past three decades since the mountain pine beetle attack.

FIGURE 1. The Flathead drainage in southeastern British Columbia.

Methods

We investigated the response by grizzly bears to the development of the valley for salvage logging across multiple spatial scales using four methods.

1. We investigated changes in vital rates of the grizzly bear population over three decades (1978–1987, 1988–1997, and 1998–2007) in an area where MPB-killed trees were intensively salvage-logged after the infestation.
2. We assessed the landscape-scale features influencing the distribution and abundance of grizzly bears by comparing detection rates from a 2007 "hair-snagging" DNA grid north of the border to data from a DNA grid completed in 2004 south of the border.
3. We tested the role of immature forest stands (age < 41 years) and road density on grizzly bear habitat selection across multiple spatial scales using VHF and GPS locations.
4. We quantified the ecological and physical attributes of sites used by grizzly bears in lodgepole pine stands and salvage-logged areas.

Results and Discussion

The analysis of the vital rates of the grizzly bear population in the lower Flathead Valley for a 30-year period showed an increasing population over the first two decades during and after salvage logging, followed by a declining population in the last decade largely because of a dramatic decline in cub production and survival. Reduced cub production and survival was likely due to a density effect caused by the increase in population size exacerbated by the decline in ungulates and huckleberries. The timing of the decline and the diets and habitat selection information suggest that the forest harvesting in response to the 1970s mountain pine beetle infestation had little to do with the changes in cub production and survival. The road building associated with the salvage harvesting did, however, increase the encounter rate of bears and people with some of the encounters lethal for the bears.

We explored the influence of landscape condition on grizzly bear distribution using the 2007 DNA (Flathead) and 2004 DNA (Glacier) hair census data and detection rates. We analyzed differences in detection rate of grizzly bears among eight zones of the Flathead drainage. Each zone corresponded to a different array of habitat and human conditions resulting from the historic pattern of mountain pine beetle infestation and management. On average, all zones on the Canadian side of the border had a higher number of bears per site per session and females per site per session than the Montana side of the border. This suggests that more bears occurred north of the border where extensive salvage logging occurred.

We tested the role of immature forest stands (age < 41 years) and road density on grizzly bear habitat selection across multiple spatial scales. During the pre-berry season, immature forest stands had a negative influence on grizzly bear habitat selection at higher scales (level 2 and 3) and a marginally positive influence at the finer scale (level 4). During the post-berry season, immature forest stands were highly irrelevant at any scale. These results are consistent with earlier research in the study area that showed young second-growth stands were ranked among the least-favoured habitats by bears (McLellan and Hovey 1995). During the pre-berry season, road density had a relatively strong negative influence on grizzly bear habitat selection at levels 2 and 3. Road density also negatively influenced grizzly bear habitat selection at level 2 during the post-berry season.

Landscape conditions that best describe mortality locations of research grizzly bears were also explored across multiple spatial scales. Road density was the most relevant predictor across scales, with grizzly bears significantly more likely to die from human causes in landscapes with increasing values of these attributes. Similarly, the distribution of cutblocks and immature stands appear to increase grizzly bear mortality risk, particularly at finer scales.

Finally, we quantified the ecological and physical attributes of sites used by grizzly bears in lodgepole pine stands and salvage-logged areas. In general, grizzly bear foods were absent in cutblocks, and in immature and mature pine stands. Of the food-related measurements, only creamy peavine (*Lathyrus ochroleucus*), a minor herbaceous food resource for grizzly bears during late May through July, significantly differed among grizzly bear use and paired random locations in mature pine stands. The seasonal-adjusted food index did not significantly differ between use and paired random locations. This suggests that at the scale tested, food resources were not patchy and (or) limiting. Snag densities within regenerating cutblocks were significantly different between grizzly bear use and paired random locations. A higher density of snags in recent cutblocks may suggest that bears are selecting these types of cutblocks for the anting opportunities.

Conclusions

The salvage-logging operations in response to the MPB outbreak in Flathead drainage has had little impact on the grizzly bear population dynamics and habitat selection patterns. The increase in roads associated with logging, however, elevated the mortality risk for grizzly bears as almost all adult bears that died were killed by people and almost all of these were shot from a road or hunting camp.

Acknowledgements

Support was provided by the B.C. Ministry of Forests and Range, the Forest Investment Account–Forest Science Program, the B.C. Ministry of Environment, US Fish and Wildlife Service, Shell Canada Ltd., University of British Columbia, Simon Fraser University, B.C. Forest Service, Forest Renewal BC, Canadian Wildlife Foundation, National Fish and Wildlife Foundation (USA), Boone and Crockett Club, National Rifle Association (USA), World Wildlife Fund, (Canada), Canadian Wildlife Service University Research

Support Fund, East Kootenay Operators (seven British Columbia forestry companies), Plum Creek Timber Ltd., Crowsnest Resources Ltd., Sage Creek Coal Ltd., BC Guides and Outfitters, and Safari International (British Columbia Chapter).

Many people assisted with various aspects of data collection, including D. Carney, C. Doyon, R. Heggs, D. Horning, F. Hovey, R. Mace, B. Noble, T. Radandt, V. Scherm, T. Their, and C. Wilson. I. Teske of the B.C. Ministry of Environment collected the reproductive data for many years and S. Robertson helped collect the grizzly bear microsite data.

References

McLellan, B.N. and Hovey, F.W. 1995. The diet of grizzly bears in the Flathead River drainage of southeastern British Columbia. Candian Journal of Zoology 73:704–712.

Young, C. 1988. Coming of age in the Flathead: How the British Columbia Forest Service contended with the mountain pine beetle infestation of southeastern British Columbia 1976–1986. B.C. Ministry of Forests, Victoria, B.C. Pest Management Report No. 10.

Abstract

Landscape strategies for mountain pine beetle management: Some stewardship implications

J. Douglas Steventon[1] and Dave Daust[2]

Presentation Abstract

We used habitat and population modelling to assess alternative management strategies for selected species in a 2.6 million ha sub-boreal landscape (Nadina Forest District) subject to an extensive mountain pine beetle (*Dendroctonus ponderosae*) outbreak. We focussed on species that were generally associated with mature forest and that represented different spatial requirements and habitat specificity. The management options considered included protection of understorey, partial cutting, timber harvest rate, cutblock size limits, and expanded use of biodiversity corridors. We conducted the analyses in the context of stochastic natural disturbance and climate change. We summarize the analyses in a Bayesian Belief Network (BBN) meta-model that incorporated the results of spatially explicit modelling of landscape conditions (disturbance, habitat quality, number of potential territories, and connectedness of habitat) with analytical population modelling. The BBN meta-model was then used to examine system response and to analyze management tradeoffs under varying beliefs about parameter plausibility. Choice of management strategy had a strong long-term effect on species recovery potential after the beetle outbreak, even with assumptions of increasing stochastic disturbance due to climate change. The choice of management strategy depended strongly on the weighting of wildlife outcomes against timber harvest outcomes, assumptions of future species demography, and on taking a long-term perspective. Understorey protection and partial cutting had the greatest potential to narrow the difference between the two resource values.

KEYWORDS: *British Columbia, climate change, landscapes, mountain pine beetle, natural disturbance, population modelling, sub-boreal, wildlife.*

Contact Information

1 Bulkley Valley Centre for Natural Resources Research and Management, and B.C Ministry of Forests and Range, Bag 6000, Smithers, BC V0J 2N2. Email: Doug.Steventon@gov.bc.ca

2 Bulkley Valley Centre for Natural Resources Research and Management, and Consultant, 12895 Cottonwood Road, Telkwa, BC V0J 2X3. Email: pricedau@telus.net

Steventon, J.D. and D. Daust. 2008. Landscape strategies for mountain pine beetle management: Some stewardship implications. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):133. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Abstract

Hydrologic effects of mountain pine beetle infestation and salvage-harvesting operations

Stephane Dubé[1] and John Rex[2]

Presentation Abstract

The mountain pine beetle infestation is changing British Columbia forests and watersheds at the landscape scale. Watersheds with pine-leading stands that are now dead may experience changes in their water balance. Forestry stakeholders in the Vanderhoof Forest District reported an increase in groundwater storage. Specifically, they report a replacement of summer ground (dry firm soil) with winter ground (wetter less firm soil) on which forestry equipment operation is difficult or impossible before freeze-up. This study was designed to identify if and where this loss of summer ground was occurring, as well as to develop a set of indicators that can be used to predict the risk of summer ground loss at the watershed level within the Vanderhoof Forest District and others.

Effective indicators were identified during an iterative process that included model refinement, prediction, and field verification over a 2-year period. A post-hoc assessment of field information selected those indicators that explained most data variability. This assessment showed that the indicators most effective at predicting the risk of wet ground areas at the watershed level were lodgepole pine content, understorey, drainage density, sensitive soils, and the topographic index. Field observations gathered during the verification process indicated that "watering-up" was not occurring in every watershed; however, where the risk of summer ground loss was high, "watering-up" could be observed along the entire hill-slope gradient. This model may also be effective in other districts given that the chosen parameters are general and use data that should be broadly available. Completion of some field verification activities is recommended to ensure model effectiveness.

KEYWORDS: *mountain pine beetle, risk assessment, risk indicators, soil hydrology, water balance.*

Contact Information

1 B.C. Ministry of Forests and Range, 1011 4th Avenue, 5th floor, Prince George, BC V2L 3H9.
Email: Stephane.Dube@gov.bc.ca

2 B.C. Ministry of Forests and Range, 1011 4th Avenue, 5th floor, Prince George, BC V2L 3H9.
Email: John.Rex@gov.bc.ca

Dubé, S. and J. Rex. 2008. Hydrologic effects of mountain pine beetle infestation and salvage-harvesting operations. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):134. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Quantifying the hydrologic impacts of mountain pine beetle and associated salvage operations in the Fraser River watershed

Markus Schnorbus[1]

Presentation Abstract

The epicentre of the current mountain pine beetle (MPB) outbreak lies squarely within the Fraser River drainage basin, where roughly 7.7 million ha of forest have been affected. At present, the affected forest area occupies approximately 30% of the drainage area of the Fraser (or 40% of the forested area), located predominantly within the Interior Plateau. Because of the massive scale of the current (and projected) infestation and associated salvage-harvest operations, the potential exists for widespread and significant local and regional hydrologic impacts. This poster describes the progress of a project that uses the Variable Infiltration Capacity (VIC) macro-scale hydrology model to quantify the impact of the MPB infestation on hydrology within the Fraser River watershed upstream of Hope, B.C. The VIC model is a spatially distributed model that is applied at a resolution of 1/16 degree (approximately 30–32 km^2) and used to quantify impacts at drainage scales ranging from 500 to 270 000 km^2. Model-driving and parameter files developed for this effort include: a gridded historical driving data set of daily temperature maxima and minima and precipitation; gridded soils data; stream routing network; and forest cover data (including leaf area index) for historical (c. 1995), current (c. 2007), and projected (hypothetical) infestation-salvage scenarios. Model outputs will include simulated streamflow at various locations along tributaries and the Fraser main stem and gridded fields of various hydrologic fluxes (i.e., snow water equivalent, soil moisture, evaporation, etc.). Hydrologic impacts will be assessed by comparing outputs generated using the various forest cover scenarios to baseline (c. 1995 forest cover) output. The project will be completed by March 2009.

KEYWORDS: *Fraser River, hydrologic modelling, hydrology, variable infiltration capacity.*

Contact Information

1 Pacific Climate Impacts Consortium, Victoria, B.C., and River Forecast Centre, B.C. Ministry of Environment, PO Box 9362 Stn Prov Govt, Victoria BC V8W 9M1. Email: Markus.Schnorbus@gov.bc.ca

Schnorbus, M. 2008. Quantifying the hydrologic impacts of mountain pine beetle and associated salvage operations in the Fraser River watershed. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):135. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Popular Summary

Snow hydrology and solar radiation in growing and deteriorating pine stands

Pat Teti[1] and Rita Winkler[2]

Presentation Abstract

The effects of mountain pine beetle-related canopy deterioration, clearcutting, and forest recovery on snow hydrology are being documented in six study areas in the British Columbia Interior—two in the Montane Spruce biogeoclimatic zone, three in the Sub-Boreal Pine–Spruce zone, and one in the Sub-Boreal Spruce zone. Each study area has between five and seven plots, including one in a recent clearcut, one or two in partially recovered blocks, and at least two in old stands attacked by beetles. Two plots are in stands that were severely attacked in 1980. Three study areas also have plots in immature natural stands between 40 and 75 years old. Snow surveys started in 2006 and plot characteristics are being documented with detailed tree measurements, aerial photography, and fisheye canopy photography. Plot average canopy gap fractions and radiation transmittances calculated from fisheye photographs explained most of the variability in plot average snow accumulation and ablation rates. The highest snow accumulation and snow ablation rates occurred in managed stands logged 2–15 years earlier and the lowest occurred in 30-year-old managed stands and healthier multilayered old stands. Grey-attack pine stands had snow accumulation and ablation rates that were between those extremes. Results suggest that harvesting beetle-attacked pine stands will increase snow accumulation and ablation rates for 10–15 years, but that after 30 years both of those parameters will be lower in healthy managed stands than in attacked stands that were retained.

KEYWORDS: *forest recovery, mountain pine beetle, snow hydrology.*

Contact Information

1 B.C. Ministry of Forests and Range, Southern Interior Region, 515 Columbia Street, Kamloops, BC V2C 2T7. Email: Pat.Teti@gov.bc.ca

2 B.C. Ministry of Forests and Range, Southern Interior Region, 515 Columbia Street, Kamloops, BC V2C 2T7. Email: Rita.Winkler@gov.bc.ca

Teti, P. and R. Winkler. 2008. Snow hydrology and solar radiation in growing and deteriorating pine stands. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):136–138. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Introduction

The effects of mountain pine beetle-related canopy deterioration, clearcutting, and forest recovery on snow hydrology are being documented in six study areas in the British Columbia Interior—two in the Montane Spruce biogeoclimatic zone, three in the Sub-Boreal Pine–Spruce zone, and one in the Sub-Boreal Spruce zone. Each study area has between five and seven plots, including one in a recent clearcut, one or two in partially recovered blocks, and at least two in old stands attacked by beetles. Two plots are in stands that were severely attacked in 1980. Three study areas also have plots in immature natural stands between 40 and 75 years old. Snow surveys started in 2006 and plot characteristics are being documented with detailed tree measurements, aerial photography, and fisheye canopy photography.

Snow Accumulation, Snow Ablation, and Canopy Properties

Overhead canopy gap fraction within 30° of the zenith was a good predictor of plot average peak snow accumulation, explaining 60–80% of the variance in four of the study areas. The stands with the highest canopy gap fractions were those that had been logged within the last 15 years and they also had the highest average snow storage. The lowest canopy gap fractions were in mature stands having mostly green and multilayered canopies and in managed stands more than 30 years old. Those types of stands had 30–40% lower snow storage than nearby clearcuts. Gap fractions and peak snow storage in grey-attack stands were midway between those of unrecovered (0–10 years old) and highly recovered (> 30 years old) cutblocks.

Plot average transmitted solar radiation in mid-spring was a good predictor of plot average snow ablation rates, explaining 56–91% of the variance in five of the six study areas. Not surprisingly, plot average overhead gap fractions and plot average radiation transmittances were highly correlated with an $r^2 = 0.95$ (Figure 1). Therefore, plots that had more canopy had lower ablation rates as well as lower peak snow storage. Grey-attack pine stands had moderate snow ablation rates. Since our plots included growing and deteriorating stands with a wide range of canopy conditions, these observations indicate that snow accumulation and snow ablation rates decrease with stand growth and increase with stand deterioration in ways that are largely explicable in terms of logical canopy parameters.

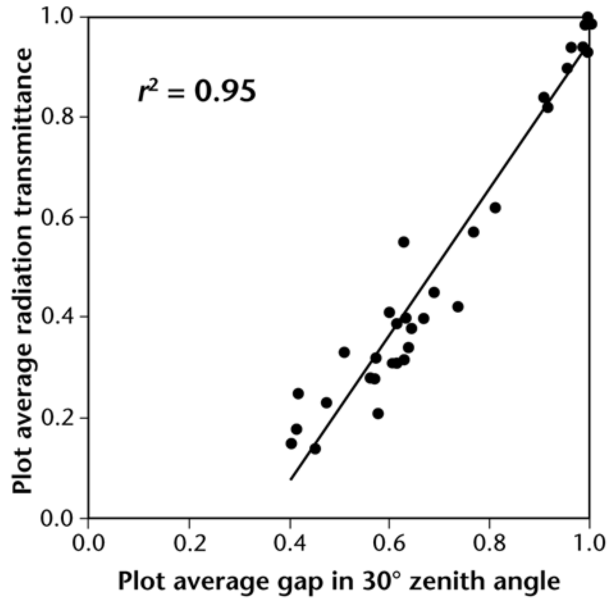

FIGURE 1. Plot average radiation transmittance versus plot average canopy gap around the zenith.

Figure 2 is a scattergram of plot average radiation transmittances versus stand ages. When plots in recovering cutblocks and those in young, natural even-aged stands are grouped (as shown in the two ellipses), the trends of decreasing radiation transmittances in the first decades after stand replacement are apparent. The data indicate that the recovery of radiation transmittance occurs about twice as fast in managed pine stands as in pine stands that regenerate naturally after wildfires. Similar patterns are observed in snow accumulation versus stand age and ablation rate versus stand age.

Conclusions

In spite of the structural complexity of pine stands that were attacked up to 25 years ago, those types of stands in our sample displayed less variability in snow hydrology and the canopy properties that regulate them than do managed stands up to age 35. However, other types of naturally disturbed pine stands might exhibit more variability than we observed, such as what could occur during the first decade or two after wildfire or after severe blowdown in the absence of natural regeneration.

For 10–15 years after logging, managed pine stands are expected to have higher snow accumulation and

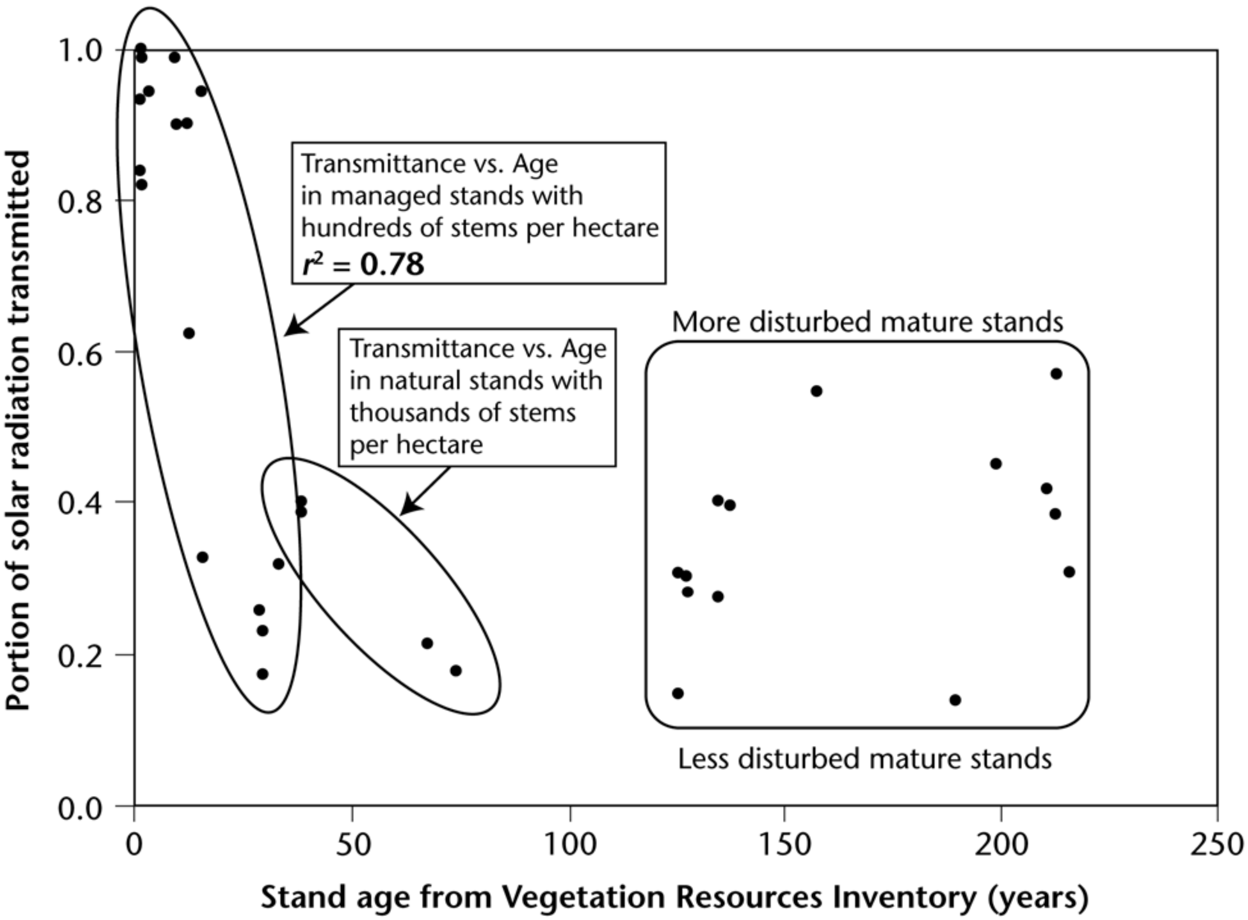

FIGURE 2. Scattergram of plot average radiation transmittances versus stand ages.

snow ablation rates than severely attacked old pine stands. Within 30 years, this situation is expected to reverse because healthy managed pine stands should be almost fully recovered hydrologically whereas attacked stands would be expected to have low to moderate recovery, depending on their rates of blowdown and regeneration. Although salvage logging dead pine stands would be expected to reduce hydrologic risk within two to three decades of logging, it is expected to increase risk for about the first 15 years. Therefore, the percent of watershed area and locations of cutblocks less than 15 years old should be managed carefully in watersheds where peak streamflows are a concern in beetle-attacked watersheds.

Abstract

Development of a hydrologic process model for mountain pine beetle-affected areas in British Columbia

Markus Weiler[1], Klemens Rosin[2], and Cornelia Scheffler[3]

Presentation Abstract

The infestation of the mountain pine beetle (MPB) has become a major threat to the natural habitat of British Columbia. Current estimates are that about 13.5 million ha of forest cover are affected by MPB. This forest cover is a key modifier of a watershed's peak flow regime. The peak flow generally increases when forest cover is reduced due to natural and (or) human disturbances. In this project, a hydrological model will be applied to predict this peak flow increase. Since major parts of the Interior of British Columbia have only a limited number of gauging stations (or are even ungauged), the goal was to develop a model that does not rely on complex data inputs for its validation and calibration procedures. The model developed consists of an input component and a runoff generation component. The input component determines the mean annual snowmelt and maximum rainfall based on climatic data. This information is then used to determine the time and the capacity of the peak flow for every third-order watershed. The runoff generation component delineates the hydrologic processes (i.e., Hortonain overland flow, saturation overland flow, and shallow surface flow). This delineation is based on factors such as topography, slope, aspect, wetness index, drainage pattern, and drainage density. Combining the two components, the model computes a map of peak flow contribution that can be used to assess sensitive areas for peak flow production. This poster focusses on the conceptual presentation of the hydrological model. It highlights initial results and points out further developments.

KEYWORDS: *dominant runoff processes, hydrological modelling, peak flow.*

Contact Information

1 Institut für Hydrologie, Universität Freiburg, Fahnenbergplatz, 79098 Freiburg, Germany, and Forest Resources Management, University of British Columbia, Forest Sciences Centre, 2424 Main Mall, Vancouver, BC V6T 1Z4. Email: Markus.Weiler@ubc.ca

2 Forest Resources Management, University of British Columbia, Forest Sciences Centre, 2424 Main Mall, Vancouver, BC V6T 1Z4. Email: rosink@interchange.ubc.ca

3 Forest Resources Management, University of British Columbia, Forest Sciences Centre, 2424 Main Mall, Vancouver, BC V6T 1Z4. Email: cscheff@interchange.ubc.ca

Weiler, M., K. Rosin, and C. Scheffler. 2008. Development of a hydrologic process model for mountain pine beetle-affected areas in British Columbia. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):139. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Popular Summary

Using genetic analyses to infer mountain pine beetle population structure and dispersal patterns in British Columbia and Alberta

Nicholas V. Bartell[1], Staffan Lindgren[2], Janice Cooke[3], Corey Davis[4], Karen Mock[5], and Brent W. Murray[6]

Presentation Abstract

The mountain pine beetle (MPB) is an eruptive insect that is currently causing an outbreak of record size in western Canada. The longstanding lack of long-distance MPB dispersal data has limited our understanding and management of MPB outbreaks. Our goal was to characterize the genetic structure of western Canadian MPB populations, from which dispersal patterns may be inferred. We analyzed 35 MPB stands in British Columbia and Alberta at six microsatellite loci. The MPB exhibited strong and significant population structure. This structure was partitioned into a Northern and Southern group. The genetic structure and observed patterns of diversity are consistent with the notion of post-glacial recolonization and climate-driven differences in MPB population dynamics. Using our genetic data, we inferred the historical movement patterns of the MPB in western Canada. We found no evidence that the infestation spread from an epicentre in Tweedsmuir Provincial Park. Our data support multiple sources for the current outbreak. Management recommendations are included.

KEYWORDS*:* Dendroctonus ponderosae*, dispersal patterns, mountain pine beetle, population genetics, scolytidae.*

Contact Information

1 Ecosystem Science and Management, University of Northern British Columbia, 3333 University Way, Prince George, BC V2N 4Z9. Email: d.bartell@shaw.ca

2 Ecosystem Science and Management, University of Northern British Columbia, 3333 University Way, Prince George, BC V2N 4Z9. Email: lindgren@unbc.ca

3 University of Alberta, Department of Biological Sciences, CW460 Biological Sciences, Edmonton, AB T6G2E9. Email: janice.cooke@ualberta.ca

4 University of Alberta, Department of Biological Sciences, M547 Biological Sciences, Edmonton, AB T6G 2E9. Email: cordavis@ualberta.ca

5 Department of Wildlands Resources, Utah State University, 5230 Old Main Hill, Logan, UT USA 84321. Email: karen.mock@usu.edu

6 Ecosystem Science and Management, University of Northern British Columbia, 3333 University Way, Prince George, BC V2N 4Z9. Email: murrayb@unbc.ca

JEM* — *Volume 9, Number 3 *Published by* FORREX *Forum for Research and Extension in Natural Resources*

Bartell, N.V., S. Lindgren, J. Cooke, C. Davis, K. Mock, and B.W. Murray. 2008. Using genetic analyses to infer mountain pine beetle population structure and dispersal patterns in British Columbia and Alberta. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):140–142. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Introduction

The endemic mountain pine beetle (*Dendroctonus ponderosae* Hopkins; MPB) is the most destructive pest of pine forests in western North America. A current MPB outbreak in British Columbia has caused new tree mortality over a record 10.1 million ha based on B.C. Ministry of Forests and Range surveys at the end of 2007. This infestation has extended into Alberta and is among the largest insect outbreaks in Canadian history.

Numerous plausible reasons may explain the spread of the current MPB outbreak. Outbreaks in Alberta may have originated via dispersal from numerous, apparently isolated British Columbia infestations. Indeed, MPB populations are endemic to many regions of British Columbia. In addition, the infestation may have originated from an epicentre in Tweedsmuir Provincial Park as this was one of the first regions to reach epidemic status during the current outbreak. The MPB does disperse long distances. Single events have moved beetles hundreds of kilometres (e.g., the summer 2006 flight into the Peace River region of British Columbia and documented flights across the Albertan prairies during the 1980s). Long-distance bark beetle dispersal is thought of as a passive process in which emerging beetles are caught in updrafts, are moved above the stand canopy, and are transported by atmospheric winds.

A lack of data on the sources of origin of long-distance MPB dispersal events has seriously limited our understanding and management of the current outbreak. The study of long-range bark beetle dispersal has traditionally been methodologically constrained. Mark-recapture techniques are not feasible and past genetic techniques have failed to yield significant results. We used a robust genetic marker system, microsatellite analysis, which uses codominant genomic markers to determine unique individual MPB genotypes. Patterns of genetic variation can be studied by analyzing genotypes among individuals and populations. Our goal was to determine the MPB's population genetic structure in western Canada and to use this information to infer dispersal patterns.

Methods

In the summers of 2005, 2006, and 2007, MPB were collected before dispersal flights from 35 stands throughout British Columbia and into Alberta. At each stand, 13–20 infested trees separated by 10 m or more were selected. At least four individual offspring were sampled from each of four separate breeding galleries per tree. Only lodgepole pine (*Pinus contorta* Douglas var. *latifolia*) trees were sampled to avoid bias due to potential host-associated MPB preferences. Beetles were stored in 95% ethanol until DNA analysis took place in the lab. DNA was extracted from about 48 MPB per stand (each beetle from a different gallery). Beetles were manually genotyped at six microsatellite loci through PCR-amplification and fragment analysis. Before using any of the microsatellite loci, all were screened against DNA isolated from microbes associated with the MPB to ensure beetle specificity.

Results and Discussion

We found evidence for population structure among MPB stands in western Canada (SAMOVA: $FST = 0.05794$; $P < 0.00001$). This population structure was subdivided into a Northern and Southern group. The existence of a Northern and Southern group was supported by three different statistical algorithms (Arlequin – AMOVA; Structure – Bayesian likelihood; SAMOVA – Simulated annealing). The program "Arlequin" was used to conduct an Analysis of Molecular Variance (AMOVA), which determines population structure by calculating the genetic distance among all the individuals in a study and by partitioning genetic variance among sampling locations and within sampling locations' components. The program SAMOVA (Spatial Analysis of Molecular Variance) determines population structure by grouping sampling locations to maximize the among-group genetic variance. In contrast, the program "Structure" determines population structure by grouping individuals with like genotypes. Structure also detected a Northern and Southern group, but divided the groups further south than the SAMOVA analysis.

We also found strong evidence of North–South genetic diversity gradients for the MPB in western Canada. Genetic diversity was highest in the south and declined with increasing distance northwards. We also detected strong and significant isolation by distance in the Southern, but not the Northern, group. Isolation by distance (IBD) is a phylogeographic pattern in which geographically proximate populations are more likely to interbreed, causing higher genetic relatedness. Under IBD, relatedness among populations declines linearly with geographic distance (as found in the Southern MPB group).

The existence of Northern and Southern MPB groups is probably the result of post-glacial recolonization and differential population dynamics. Under a hypothesis of post-glacial recolonization, the Southern populations are the oldest; thus, the Northern populations are the youngest and are probably heavily influenced by genetic drift (founder events and [or] population bottlenecks), which causes reduced genetic diversity. A hypothesis of differential MPB population dynamics asserts that southern British Columbia is more climatically suitable for MPB populations, leading to more stable populations, more frequent outbreaks, and higher genetic diversity compared to northern British Columbia.

At a provincial scale, the current outbreak probably developed from multiple infestations and not from a single epicentre in Tweedsmuir Provincial Park. The lack of IBD in the north suggests that long-distance dispersal events among populations are typical. In contrast, the presence of strong IBD in the south suggests that movements among populations are stepwise through weaknesses in barriers, such as mountain ranges. These results confirm a prior spatio-temporal analysis of the current MPB epidemic.

Conclusions and Future Work

- The current western Canadian MPB outbreak has developed from many genetically distinct source populations.
- The genetic patterns in southern British Columbia are consistent with ongoing stepwise dispersal among populations.
- The genetic patterns in northern British Columbia are consistent with long-distance dispersal events.
- Our results suggest that regional containment, in combination with prevention (seral and tree species diversity), may be more effective for outbreak management in the Southern group than in the Northern group.
- Our study represents a snapshot of the current MPB outbreak; multi-year sampling at a similar spatial scale (one stand every 100 km) should be extended over the MPB's North American range.
- Annual MPB population genetic surveillance should be conducted by the provincial government as part of B.C. Ministry of Forests and Range operations; such surveillance would cost less than $20 000 annually and would provide critical data on population trends and dispersal patterns.

Acknowledgements

Beetle samples were collected with the assistance of undergraduate students, E. Carlson and B. Shelest, private consultants, M. Duthie-Holt and M. Cleaver, and numerous Canadian Forest Service, B.C. Ministry of Forests and Range, Provincial and National Park employees throughout British Columbia and Alberta. The authors gratefully acknowledge the financial assistance provided by the University of Northern British Columbia, the Forest Investment Account–Forest Science Program, Genome BC and Genome Alberta (the TRIA Project – MPB system genomics), and the U.S. Department of Agriculture Forest Service Rocky Mountain Research Station.

Induced terpene defence response of lodgepole and jack pine

Erin Clark[1], Dezene Huber[2], and Allan Carroll[3]

Presentation Abstract

The primary host of the mountain pine beetle (*Dendroctonus ponderosae*; MPB) in British Columbia is lodgepole pine (*Pinus contorta* var. *latifolia*), but the insect is capable of utilizing several *Pinus* species including jack pine (*Pinus banksiana*), stands of which have been found to be infested by MPB. One defence utilized by pines against the MPB is their terpene-based resins. Terpenes have many functions including toxicity to invading insects. Beetles also use them as precursors to components of their aggregation pheromones. Comparison of jack and lodgepole pine defences may help predict risks of beetle infestation in new areas. We sampled phloem tissue from three populations of pine: lodgepole pine stands in southern and central British Columbia, and a jack pine stand in Alberta. Samples were analyzed for presence and quantity of 26 terpenes after wounding the trees to simulate beetle attack. Samples were taken at three time points: just before wounding, 2 days after wounding, and 14 days after wounding. The results showed that jack pine had a lower increase in a toxic terpene (i.e., 3-carene) in response to wounding than did the lodgepole pine ($p < 0.007$) and had higher levels of induced α-pinene, a terpene utilized by MPB to produce aggregation pheromone ($p < 0.001$). This may indicate that MPB could do as well on jack as lodgepole pine. In fact, the insect may actually be able to attract more conspecifics to one tree, increasing its ability to overwhelm chemical defences for successful colonization.

KEYWORDS: *defence response, jack pine, lodgepole pine, mountain pine beetle, terpenes.*

Contact Information

1 University of Northern British Columbia, 3333 University Way, Prince George, BC V2N 4Z9.
Email: eclark1@unbc.ca

2 University of Northern British Columbia, 3333 University Way, Prince George, BC V2N 4Z9.
Email: huber@unbc.ca

3 Natural Resources Canada, Pacific Forestry Centre, 506 West Burnside Road, Victoria, BC V8Z 1M5.
Email: acarroll@pfc.cfs.nrcan.gc.ca

Clark, E., D. Huber, and A. Carroll. 2008. Induced terpene defence response of lodgepole and jack pine. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):143. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Abstract

Effect of terrain on insect deposition and population establishment in northeastern British Columbia

Honey C. Giroday[1] and Brian H. Aukema[2]

Presentation Abstract

Large numbers of mountain pine beetle have crossed the Rocky Mountains from central to northeastern British Columbia due to aeolian dispersal. Previous research in the field of aerobiology has demonstrated that atmospheric processes within the boundary layer greatly influence dispersal, deposition, and the eventual establishment of infestations. In particular, landform-induced deposition is thought to greatly influence mesoscale settlement patterns of insects in this region. We present an analysis of aerial and ground survey data collected annually from 2002 to 2006 to identify dominant patterns of dispersal in relation to susceptible host distribution, using susceptibility class as a surrogate, and topography. Results of contingency tests indicate that susceptibility class influences likelihood of infestation, with more area than expected being colonized in habitat of higher susceptibility. Pattern of infestation relative to topography is found to be significantly different from uniform, with some landforms (e.g., U-shaped valleys and canyons) experiencing greater than expected establishment relative to others.

KEYWORDS: *aerobiology, landscape ecology, mountain pine beetle.*

Contact Information

1 University of Northern British Columbia, 3333 University Way, Prince George, BC V2N 4Z9. Email: girodayh@unbc.ca

2 Canadian Forest Service, and University of Northern British Columbia, 3333 University Way, Prince George, BC V2N 4Z9. Email: Brian.Aukema@nrcan.gc.ca

Giroday, H.C. and B.H. Aukema. 2008. Effect of terrain on insect deposition and population establishment in northeastern British Columbia. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):144. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Abstract

The TRIA Project: Mountain pine beetle system genomics

Dezene P.W. Huber[1] and the British Columbia–Alberta Research Team[2]

Presentation Abstract

The devastating infestation of the mountain pine beetle (*Dendroctonus ponderosae*) that has swept through the pine forests of British Columbia is the result of complex interactions between the genomes of three components: the beetle, its fungal associates, and host pine trees. Genome British Columbia and Genome Alberta are jointly funding multidisciplinary Phase I genomics research aimed at deciphering these interactions. Over the next 2 years, the British Columbia–Alberta research team will produce many valuable resources, including: a complete genome sequence for the important fungal associate, *Ophiostoma clavigerum*; sequences of expressed genes in the beetle; and sequences of expressed genes in lodgepole pine (*Pinus contorta*) and jack pine (*P. banksiana*). Sequence information will be deposited into public databases and will be used to identify genes involved in control and timing of fungal spore germination, detoxification of the host tree's secondary defence metabolites by the fungi and beetle, beetle pheromone biosynthesis and olfaction, insect cold tolerance physiology, and in the chemical and physical defence responses of the pines. The new sequence data will also aid in development of genetic population markers to support detailed tracking of specific traits important to the spread of the epidemic. The information gleaned in Phase I will be used to support further Phase II research on specific aspects of the physiology and population genetics of the interacting organisms, and will be used to support better predictive models for understanding the continued spread of the infestation, which now threatens to move further east from British Columbia, through Alberta, and across Canada's valuable boreal forests.

KEYWORDS: Dendroctonus ponderosae, *genome, genomics,* Ophiostoma clavigerum, Pinus banksiana, Pinus contorta, *physiology, population genetics.*

Contact Information

1 University of Northern British Columbia, 3333 University Way, Prince George, BC V2N 4Z9. Email: huber@unbc.ca

2 University of Northern British Columbia, University of British Columbia, University of Alberta, Canadian Forest Services, Natural Resources Canada, and Canada's Michael Smith Genome Sciences Centre, Prince George, BC.

Huber, D.P.W. and the British Columbia–Alberta Research Team. 2008. The TRIA Project: Mountain pine beetle system genomics. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):145. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Abstract

Chip off the old block? Effects of early adult experience and present host on female colonization and male joining behaviour in mountain pine beetle colonizing pine versus spruce

Fraser R. McKee[1] and Brian H. Aukema[2]

Presentation Abstract

Throughout the central interior of British Columbia, the mountain pine beetle (*Dendroctonus ponderosae* Hopkins; MPB) is attacking interior hybrid spruce (*Picea glauca* × *engelmannii*) with increasing frequency, in some cases leading to successful colonization and reproduction. In MPB, females are the host-selecting sex. Females emit aggregation pheromones while tunnelling, attracting male and female conspecifics. This study examines the effect of early adult experience within the host species of origin (i.e., natal host) and present host species on host acceptance behaviour of female MPB and joining behaviour by male MPB. Females reared naturally from lodgepole pine (*Pinus contorta*) and spruce hosts were placed in pine and spruce logs for 24 hours before measuring host acceptance/rejection. Females that had developed within spruce had higher rates of host acceptance than females that had developed in pine in both pine and spruce host species. Additionally, spruce appears to be a more accepted species of host than pine. Male MPB preferentially selected females that had developed within the same species of natal hosts as themselves, regardless of the host species in which the female was located. Females within hosts similar to their natal species were not preferentially joined by males when compared to females in hosts dissimilar to their natal host.

KEYWORDS: *female colonization, host species, hybrid spruce, male joining behaviour, mountain pine beetle, pine.*

Contact Information

1 University of Northern British Columbia, 3333 University Way, Prince George, BC V2N 4Z9. Email: fraser_mckee@hotmail.com

2 University of Northern British Columbia, and Canadian Forest Service, 3333 University Way, Prince George, BC V2N 4Z9. Email: Brian.Aukema@nrcan.gc.ca

McKee, F.R. and B.H. Aukema. 2008. Chip off the old block? Effects of early adult experience and present host on female colonization and male joining behaviour in mountain pine beetle colonizing pine versus spruce. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):146. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Genetic variation of lodgepole pine chemical and physical defences that affect mountain pine beetle attack and tree mortality

Dan S. Ott[1], Dezene P.W. Huber[2], Alvin D. Yanchuk[3], and Kimberly F. Wallin[4]

Presentation Abstract

We quantified genetic variation of lodgepole pine defence mechanisms against mountain pine beetle (*Dendroctonus ponderosae*; MPB) and its fungal complex, *Grosmannia clavigera*. Based on previous work, we selected 45 open-pollinated families from a population of 180, with the number of trees per family ranging from 16 to 26 (for a total of 887 trees) across two sites. During the summer of 2006, we quantified chemical and physical defensive responses to simulated attack by the MPB fungal complex. These responses included: resin flow, host compartmentalization response to fungal inoculation, and constitutive and induced terpenes. During the summer and fall of 2007, we further assessed tree height, diameter at breast height, bark texture, tree mortality, MPB presence, attack density, reproduction, and brood development, as well as the presence of hypersensitivity reactions by the tree to MPB. Changes in lesion length were significantly different between families at the two time intervals after fungal inoculation. Our data suggests variation in terpene makeup pre- and post-induction of simulated MPB attack are significantly different among families, as are traits in lodgepole pine that affect MPB colonization. For traits that had significant heritabilities, family mean correlations among these traits were determined. Constitutive (pre-induction) α-3-carene was negatively correlated with family mean mortality. The frequency of hypersensitivity reactions were negatively correlated with MPB gallery production, reproduction, and brood development. Results suggest that several specific lodgepole pine tree defences are heritable, and α-3-carene and hypersensitivity reaction frequency negatively affect MPB-induced tree mortality and likely their subsequent fitness.

KEYWORDS: *defensive response, genetic variation, lodgepole pine, mountain pine beetle.*

Contact Information

1 University of Northern British Columbia, 3333 University Way, Prince George, BC V2N 4Z9. Email: ott@unbc.ca

2 University of Northern British Columbia, 3333 University Way, Prince George, BC V2N 4Z9. Email: huber@unbc.ca

3 B.C. Ministry of Forests and Range, Research Branch, PO Box 9519 Stn Prov Govt, Victoria BC V8W 9C2. Email: Alvin.Yanchuk@gov.bc.ca

4 University of Vermont, 321 Aiken Center, Burlington, VT USA 05404. Email: kwallin@uvm.edu

Ott, D.S., D.P.W. Huber, A.D. Yanchuk, and K.F. Wallin. 2008. Genetic variation of lodgepole pine chemical and physical defences that affect mountain pine beetle attack and tree mortality. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):147. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Genetic variation of attack and resistance in lodgepole pine to mountain pine beetle

Alvin D. Yanchuk[1], Nick Ukrainetz[2], and Kimberly F. Wallin[3]

Presentation Abstract

We examined variation of attack to mountain pine beetle (*Dendroctonus ponderosae*; MPB) in a 20-year-old lodgepole pine open-pollinated (OP) family trial composed of 180 OP parent trees originating from local and non-local populations. Trees were scored in the summer of 2005 and 2006 for traits relating to attack and survival. Successful attack was assumed by the presence of dead crowns, as well as the presence pitch tubes (PTP05) from MPB. Eighty-seven percent of the trees had green crowns (GC05) with family mean differences ranging from 46% to 100%, and 7% to 100% for PTP05. Significant genetic variation was found for GC05 (heritability [h2] = 0.20 [s.e. = 0.10]) and PTP05 (h2 = 0.26 [s.e. = 0.9]). Some population structure is present for these "resistance" attributes. The genetic correlation between 10-year height growth and PTP05 was 0.19, indicating that faster growing families/genotypes are slightly more subject to attack. Attack continued through 2006 and only 17% of the trees remained alive, but interestingly the heritability of survival in 2006 was the same as in 2005. Of the 17% surviving trees to date, 9% had the classic hypersensitive response to an MPB attack, but this response did not have a significant h2. It is clear that MPB makes important host choices, and these have a genetic basis. This information also makes important contributions to our current forest management approaches in salvage-logging of MPB-attacked stands. Further research is under way to improve our understanding of the actual "resistance" mechanisms at work in lodgepole pine to MPB.

KEYWORDS: *bark beetles, heritability, pest resistance.*

Contact Information

1 B.C. Ministry of Forests and Range, Research Branch, PO Box 9519 Stn Prov Govt, Victoria BC V8W 9C2. Email: Alvin.Yanchuk@gov.bc.ca

2 B.C. Ministry of Forests and Range, Research Branch, 3401 Reservoir Road, Vernon BC V1B 2C7. Email: Nicholas.Ukrainetz@gov.bc.ca

3 University of Vermont, 321 Aiken Center, Burlington, VT USA 05404. Email: kwallin@uvm.edu

Yanchuk, A.D., N. Ukrainetz, and K.F. Wallin. 2008. Genetic variation of attack and resistance in lodgepole pine to mountain pine beetle. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):148. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Quesnel forest bio-economy project

Jim Savage[1]

Presentation Abstract

This poster describes efforts by Quesnel, B.C. to define a "forest bio-economy" roadmap that we hope will lead to sustainable businesses and hundreds of jobs. It is crucial that beetle-affected communities like Quesnel extract as much sustainably derived economic value from biomass and other resources. This is also critically important for the economies of both Canada and British Columbia. Forestry towns are generally "profit centres" for senior governments, but many such towns are struggling as the forestry sector faces ever greater global competition. The timing is good to pursue the bio-economy vision. In parallel with forest industry problems, world petroleum production is facing challenges that will likely lead to even higher prices. That, along with global environmental problems, is sparking billions of dollars of research worldwide on how to make "bio-products"—that is, energy, chemicals, and other products from organic materials like trees. In addition to industrial opportunities, many chances exist to create businesses and jobs (e.g., agroforestry and non-timber forest products). Although "bio-energy" is frequently prescribed as a major economic solution for places like Quesnel, it creates relatively few jobs. The Quesnel Community and Economic Development Corporation's (QCEDC) work in this arena therefore strives to go beyond "just burning it." That said, some bio-energy approaches are competitive now, and a key priority for QCEDC is identifying technologies that can integrate with existing industrial operations to reinforce their competitiveness and employment benefits. The project currently includes about 20 partners, including industrial firms, utilities, universities, research institutions, and government agencies.

KEYWORDS: *beetle-affected communities, bio-economy, Quesnel, sustainable business.*

Contact Information

1 Quesnel Community and Economic Development Corporation, 339A Reid Street, Quesnel, BC V2J 2M5.
Email: jsavage@quesnelcorp.com

Savage, J. 2008. Quesnel forest bio-economy project. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):149. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Understanding the human dimensions of the mountain pine beetle infestation: Lessons learned from the First Nations Mountain Pine Beetle Initiative

Natasha Caverley[1]

Presentation Abstract

For the 103 British Columbia First Nations territories affected by the mountain pine beetle (MPB) infestation, this disaster threatens the long-term economic, stewardship, and socio-cultural aspects of First Nations' traditional ways of life. A MPB-impacted forest is less productive of traditional foods and medicines. In other situations, the spiritual and cultural aspects of the forest are affected (e.g., disruption of ceremonial sites). The loss of wildlife habitats makes traditional hunting, trapping, and gathering more difficult. In addition, hydrologic changes due to higher runoff and greater soil erosion lead to impacts on salmon habitats.

In general, the indigenous worldview sees people, landscape, and living resources as a spiritual whole. Recognizing the instrumental role that First Nations people play in mitigating the effects of the MPB infestation, discussions were initiated in September 2005 to identify synergies between First Nations, the governments of British Columbia and Canada, and the broader community. Based on these discussions, the First Nations Mountain Pine Beetle Initiative (FNMPBI) was established in April 2006 to harmonize First Nations and government strategic partnerships in the co-management of the MPB outbreak. Utilizing the Balanced Scorecard approach, the FNMPBI examined key MPB theme areas such as community protection, economic sustainability, ecosystem stewardship, engagement of First Nations, and retention of First Nations cultural values. This poster shares, from an indigenous perspective, lessons learned from the FNMPBI's harmonized strategic planning sessions regarding the human dimension of the MPB epidemic.

KEYWORDS: *Balanced Scorecard, First Nations, human relations, multi-agency initiatives, strategic planning.*

Contact Information

1 First Nations Mountain Pine Beetle Initiative, 8845 Haro Park Terrace, North Saanich, BC V8L 3Z3.
Email: ncaverley@shaw.ca

Caverley, N. 2008. Understanding the human dimensions of the mountain pine beetle infestation: Lessons learned from the First Nations Mountain Pine Beetle Initiative. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):150–153. URL: *http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf*

Introduction

I call to the East, where the Father ascends
to all Mother Earth where life begins.
I fly through the cedars, pines, willows, and birch
as animals below me wander and search.
I call to the South, to the land down below.
Turtle stands silent, as man strings his bow
to hunt food and fur for his kin before snow.
A life will end so others will grow . . .

— Excerpt from "Call To The Four Sacred Winds" by Spirit Wind – Pat Poland, n.d.)

Using nature as inspiration, excerpts from Pat Poland's poem "Call To The Four Sacred Winds" reflect the interrelationships of many indigenous peoples' sense of self and personal identity to their surroundings. The natural world and its connection to local communities' sustainability is paramount within the indigenous worldview whereby people, ecosystems, and other natural resources are seen as a spiritual whole—holistic (Cajete 2000; France *et al.* 2004; Canadian Council On Learning 2007).

From an indigenous perspective, guiding values of spirituality (i.e., poetry and art), communal interactions, and celebrations of mystery aid in linking knowledge with the land base and its people to seek respectful co-existence. As it applies to the mountain pine beetle (MPB) infestation, there is continued need to recognize the instrumental role that First Nations people (e.g., local First Nations leaders, Elders, community members, and technical specialists) play in mitigating its effects on British Columbian forests. Many First Nations people innately understand that people are a natural part of the broader environment in which they live and thus have a causal relationship to their traditional territories.

British Columbia is experiencing the largest recorded MPB outbreak in North America. In early 2007, appropriately 9.2 million ha of forest were considered to be in the red-attack stage (i.e., trees turn red approximately 1 year after infestation). Therefore, MPB have had a very vivid impact on British Columbia's forests—its ecosystems, habitat, hydrology, and wildlife. The traditional territories of 103 First Nations are in areas devastated by the beetles. As a result, First Nations people see a direct threat of the beetles on their livelihood, culture, and overall quality of life.

In the spirit of the New Relationship Agreement, a major question has arisen in response to the infestation; that is, how can First Nations, the governments of British Columbia and Canada, and the broader community (including industry) work in a collaborative fashion to identify and prioritize common interests in the co-management of the infestation?

Human Dimensions of the Mountain Pine Beetle: An Indigenous Perspective

When examining the human dimensions of the MPB, major impacts on First Nations territories include, but are not limited to:

- effects on traditional harvest areas (less productivity of traditional foods and medicines);
- risks of wildfires within communities and territories;
- changes in hydrology due to higher runoff and greater soil erosion which lead to effects on salmon habitats;
- job losses in forest and timber industries; and
- losses of wildlife habitats that make traditional hunting and trapping more difficult.

First Nations people play an important role in mitigating the effects of the infestation. Many First Nations have a renewed appreciation for being stewards of the land and using a triple bottom-line approach to economic diversification—an approach that respects socio-cultural, ecological, and financial interests in First Nations MPB-affected territories. These overarching perspectives have the potential to serve as positive driving forces in implementing changes in infestation-related themes such as community protection, ecosystem stewardship, and economic sustainability.

Harmonizing Relationships: First Nations Mountain Pine Beetle Initiative

Based on the need to identify common MPB issues in a collaborative fashion, it was imperative to create a strategic, time-sensitive organizational structure that promotes co-operation in the co-management of the infestation. The First Nations Mountain Pine Beetle Initiative (FNMPBI) was established in April 1, 2006, to harmonize strategic working relationships with First Nations, government, industry, and the broader community. The initiative focusses exclusively on collaborative facilitation, planning, negotiation, and policy development relating to the MPB outbreak in First Nations communities.

As it specifically pertains to the FNMPBI's role in harmonized MPB strategic planning, the initiative employed the Balanced Scorecard approach as a means of engaging its strategic partners. Formally introduced by Robert Kaplan and David Norton (Harvard Business School) in 1992, this approach uses four sets of measures for strategic planning: financial, customer, internal business process, and learning/growth. Although originally developed for use in the private sector, the Balanced Scorecard is becoming an important part of government strategy development, particularly with multi-agency initiatives. Kaplan and Norton extended their work through the design of "strategy mapping" techniques for successful strategy implementation. Strategy maps are visual representations of "cause-and-effect" relationships among the components of a strategy.

Inspired by Aboriginal medicine wheels, Figure 1 outlines a holistic approach taken by the FNMPBI that focusses on organizational balance and equality to support collaborative, multidisciplinary strategy leading to action. Each perspective focusses on a specific theme that relates to multi-agency organizational performance.

- **Community Perspective** – What value must we deliver to our citizens?
- **Process/Program Perspective** – What processes and programs will we need to deliver those community values?
- **Financial Perspective** – How must we operate financially?
- **Learning and Growth Perspective** – What investments will be necessary to sustain our vision in the long term?

The four perspectives are intended to be interdependent to fully embrace and examine all aspects of organizational performance.

FIGURE 1. Harmonized First Nations/Government Mountain Pine Beetle Strategic Planning Framework.

Strategic First Nations and Government Theme Areas

The FNMPBI employs a tri-party approach (First Nations and the governments of British Columbia and Canada) and is broadly concerned with developing plans to ensure a harmonized response to the threats associated with the MPB infestation. At the highest level, the harmonized First Nations and Government MPB strategy has four major themes.

1. **Community Protection:** The MPB infestation has created a large fire threat to over 100 First Nations communities throughout British Columbia where timber is currently dead or dying.
2. **Sustainable Economy:** Response to the MPB infestation requires new, expanding, and emerging economic and business development.
3. **Ecosystem Stewardship:** The MPB infestation has serious consequences for agriculture, hydrology, conservation, wildlife habitat, and biodiversity. Silviculture, pest management, and other ecosystem restoration strategies are promising tools that will be required to ensure there are diverse and resilient forests on the land base.
4. **Engagement of First Nations and Protection of Cultural Values:** Embedded in the three above-mentioned themes is the need for objectives that acknowledge the engagement of First Nations and the protection of cultural values to reflect Aboriginal title and rights, mutual respect, recognition, and reconciliation.

During the 2006–2007 and 2007–2008 fiscal years, the FNMPBI facilitated harmonized planning sessions in North Saanich, Prince George, Kamloops, and Williams Lake. These sessions were intended to develop harmonized strategies for community protection, economic sustainability, and ecosystem stewardship. Overall, 85 people representing First Nations, government (municipal, provincial, and federal), industry, and the broader community engaged in our regional planning sessions on community protection, 106 people in our sustainable economy sessions, and 91 people in our ecosystem stewardship sessions.

Concluding Remarks

In our strategic planning sessions, we heard a number of people talk about First Nations values that were important in implementing harmonized MPB activities. The following is a set of values that illustrate First Nations peoples' needs regarding the co-management of the MPB outbreak.

- **We place a value on education and training to develop self-worth and internal capacity.** The need to grow First Nations capacity for local implementation of community protection, economic sustainability, and ecosystem stewardship initiatives (e.g., "in-community" technical training and knowledge sharing).
- **We place a value on being engaged, empowered, and accountable in developing our communities.** Community development is necessary to make communities an attractive place to live and work. This can only be accomplished if people are engaged, particularly First Nations youth.
- **We place a value on developing working relationships between First Nations and other British Columbians.** Building relationships and working together is important to develop collaborative MPB projects with First Nations and other British Columbians.
- **We place a value on shared, tri-party decision making.** There is a desire to develop new models of shared decision making in which First Nations are "not just another stakeholder," but full strategic partners with the governments of British Columbia and Canada.
- **We place a value on the importance of communal planning and governance.** Participants indicated that communities do not have adequate resources for effective resource management and planning. They highlighted the need for planning templates, tools, and workbooks to promote community sustainability and resiliency.

This summary is intended to serve as "lessons learned" in the design of a collaborative-based approach in harmonizing common issues facing First Nations territories affected by the MPB. One of the most powerful forces assisting the work of this initiative is the continuing development of relationships between First Nations, government, industry, and community members.

Acknowledgements

The FNMPBI is funded by the B.C. Ministry of Forests and Range, Province of British Columbia.

References

Cajete, G. 2000. Native science: Natural laws of interdependence. Clear Light Publishers, Sante Fe, N.M.

Canadian Council on Learning. 2007. The cultural divide in science education for Aboriginal learners. URL: *http://www.ccl-cca.ca/CCL/REports/LessonsInLearning/LinL20070116_Ab_sci_edu.htm*

France, M.H., R. McCormick, and M.C. Rodriguez. 2004. The "Red Road": Culture, spirituality and the sacred hoop. *In* Diversity, culture and counselling: A Canadian perspective. M.H. France, M.C. Rodriguez, and G.G. Hett (editors). Detselig Enterprises, Calgary, Alta. Chapter 20.

Poland, P. (n.d.). Call to the Four Sacred Winds. URL: *http://users.ap.net/~chenae/natpoem.html*

Abstract

Doing nothing is all right: Managing young pine stands after the beetle

Chris Hawkins[1] and Kyle Runzer[2]

Presentation Abstract

British Columbia's lodgepole pine (*Pinus contorta* Dougl. ex. Loud. var. *latifolia* Engelm.) forests are experiencing a mountain pine beetle (*Dendroctonus ponderosae* Hopkins; MPB) epidemic. It is predicted that the allowable annual cut (AAC) for the Prince George Timber Supply Area will fall below 75% of the pre-MPB AAC. The post-beetle mid-term AAC depends on no beetle attacks in stands of less than 60 years old (i.e., age classes 1, 2, and 3). In 2005, 98 pine-leading age class 1–3 stands were sampled in drier Sub-Boreal Spruce subzones west of Prince George. Ninety-two more pine-leading stands were sampled in wetter subzones east of the city in 2006, and a further 52 stands were sampled in an intermediate subzone in 2007. Our objectives were to: quantify MPB attack; document beetle-induced changes in stand structure and composition; and suggest future management actions.

Attack rates in age class 1 stands were low—generally less than 10%. On the other hand, attack rates in age class 3 stands were about 60%. Attack was high for age class 2: it ranged from 40% in the 2007 sample to 45% in the 2005 sample, and to greater than 60% in the 2006 sample. All rates exceed the 0% rate used in AAC projections: post-beetle AAC is optimistic. Six age class 2 stands with a range of MPB attack (15–96%) and various secondary structure stands (280–2350 stems per hectare) were modelled in SORTIE-ND. Three management scenarios were considered: (1) do nothing; (2) underplant the attacked stand with spruce; and (3) clear the attacked stand and replant with spruce and pine. The best scenario yield at projected rotation age (75 years from stand establishment) depended on the level of attack and amount of secondary structure. However, when the cost of the treatment was considered, the do-nothing scenario generally had the best net present value at projected rotation age.

KEYWORDS: *immature stands, modelling, mountain pine beetle, net present value, pine.*

Contact Information

1 Mixedwood Ecology and Management Program, University of Northern British Columbia, 3333 University Way, Prince George, BC V2N 4Z9. Email: hawkinsc@unbc.ca

2 Mixedwood Ecology and Management Program, University of Northern British Columbia, 3333 University Way, Prince George, BC V2N 4Z9. Email: runzerk@unbc.ca

Hawkins, C. and K. Runzer. 2008. Doing nothing is all right: Managing young pine stands after the beetle. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):154. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Abstract

What's next? Warren root collar weevil pressure in young lodgepole pine stands replanted following the mountain pine beetle outbreak

Matthew D. Klingenberg[1] and Brian H. Aukema[2]

Presentation Abstract

To counter the current outbreak of mountain pine beetle, which now affects almost 13 million ha of merchantable forest, salvage and reforestation efforts are being implemented. A concern for these efforts, however, is the migration of the Warren root collar weevil (*Hylobius warreni*) from stands with a high percentage of mature dead lodgepole pine into young replanted stands, resulting in mortality to young trees. We performed ground and aerial surveys in nine separate cutblocks with trees 7–10 years of age. Tree mortality due to Warren root collar weevil in these cutblocks was highest directly adjacent to the unsalvaged stands, and decreased progressively away from the edge into the cutblock. This gradient of mortality was exacerbated by increasing components of pine in the unsalvaged stands, moreso if most of the pine had died, and became progressively worse with time since mountain pine beetle attack. Moreover, Warren root collar weevil appear to preferentially attack the largest regenerating trees in the young cutblocks. Our results indicate that reforestation efforts will be complicated by the Warren root collar weevil when unsalvaged stands are proximate to replanted cutblocks.

KEYWORDS: *interspecific competition, lodgepole pine, mountain pine beetle, Warren root collar weevil.*

Contact Information

1 Ecosystem Sciences and Management, University of Northern British Columbia, 3333 University Way, Prince George, BC V2N 4Z9. Email: mklingenberg@gmail.com

2 University of Northern British Columbia, and Natural Resources Canada, Canadian Forest Service, 3333 University Way, Prince George, BC V2N 4Z9. Email: Brian.Aukema@nrcan.gc.ca

Klingenberg, M.D. and B.H. Aukema. 2008. What's next? Warren root collar weevil pressure in young lodgepole pine stands replanted following the mountain pine beetle outbreak. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):155. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Popular Summary

Whitebark pine: Initiating restoration efforts in British Columbia

Randy Moody[1] and Joanne Vinnedge[2]

Presentation Abstract

Whitebark pine (*Pinus albicaulis*) is a 5-needle stone pine found at high elevations throughout western North America. The distribution of whitebark pine across the landscape is almost exclusively due to the seed-caching activities of Clark's nutcrackers (*Nucifraga columbiana*). The seeds are also a very important source of food for red squirrels and grizzly bears.

Whitebark pine is blue-listed (vulnerable) in British Columbia due to a combination of threats including white pine blister rust, mountain pine beetle, climate change, and forest succession. White pine blister rust (*Cronartium ribicola*) is an exotic fungal disease that kills cone-bearing branches and eventually kills the tree. Mountain pine beetles also kill trees, including some that exhibit rust resistance. Climate change may reduce suitable habitat for whitebark pine. Fire suppression has allowed for successional replacement of whitebark pine by more shade-tolerant species.

This poster reports on two recent restoration efforts, both directed at collecting seed for the purpose of gene conservation and restoration. In the Fort St. James Forest District, 145 000 seeds were collected, helping to markedly increase the provincial seed bank numbers. The project also provided a valuable opportunity to increase awareness and understanding about a threatened species. Further south in Manning Park, 18 500 seeds were collected with 10 500 sown directly into local restoration areas, and the remaining seeds directed to seedling production projects. The locations of seeds planted in restoration areas were mapped for future monitoring.

KEYWORDS: *mountain pine beetle, restoration, whitebark pine.*

Contact Information

1 Ecology, Timberline Natural Resource Group, 401–958 West 8th Avenue, Vancouver, BC V5Z 1E5.
Email: randy.moody@timberline.ca

2 B.C. Ministry of Environment, PO Box 100, 2537 Stones Bay Road, Fort St. James, BC V0J 1P0.
Email: Joanne.Vinnedge@gov.bc.ca

Moody, R. and J. Vinnedge. 2008. Whitebark pine: Initiating restoration efforts in British Columbia. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):156–158. URL: *http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf*

Background

Whitebark pine (*Pinus albicaulis*) is a 5-needle stone pine found at high elevations throughout western North America. In British Columbia, it occurs in the driest and coldest regions of the Engelmann Spruce–Subalpine Fir and Mountain Hemlock biogeoclimatic zones from the United States border north to the vicinity of Takla Lake.

Whitebark pine produces large, wingless seeds in indehiscent cones, characteristics resulting from its co-evolution with the Clark's nutcracker (*Nucifraga columbiana*). The nutcracker's strong bill allows it to access the seeds, which it buries in small food caches; forgotten caches may subsequently germinate new whitebark pine seedlings. The distribution of whitebark pine across the landscape is almost exclusively due to the seed-caching activities of these birds.

The large, nutritious seeds are also a very important source of food for red squirrels and grizzly bears. Red squirrels often cache whitebark cones in middens for use at a later time; grizzly bears will often raid these middens for an easy source of pre-denning food.

In 2007, the provincial status of whitebark pine was downgraded from yellow (apparently secure) to blue (vulnerable), due to the combination of threats from white pine blister rust, mountain pine beetle, forest succession, and climate change (BC Conservation Data Centre 2008). White pine blister rust (*Cronartium ribicola*) is an exotic fungal disease that kills cone-bearing branches, and weakens or kills the tree. Although some individuals exhibit characteristics of rust resistance, whitebark pine is highly susceptible to white pine blister rust and widespread infection levels have been observed throughout its range (Zeglen 2002). While white pine blister rust has been the main cause of whitebark pine decline, recent surveys indicate extensive mountain pine beetle infestations and mortality in whitebark pine (Campbell and Carroll 2007). Most alarmingly, the mountain pine beetle is killing trees that exhibit rust resistance, negatively affecting the potential for natural recruitment of rust-resistant seedlings on the landscape.

Climate change may lead to a reduction in suitable habitat over the next 100 years, particularly in southern British Columbia. This may also result in a northward shift of its provincial range (Hamann and Wang 2006). Studies are currently under way to assess the adaptability of the species in making this northward advance (S. Curtis-Maclean, pers. comm.).

Also contributing to the decline of whitebark pine is its successional replacement by more shade-tolerant species due to fire suppression. Whitebark pine typically pioneers sites following disturbance; however, it is a poor competitor once other species become established. The Clark's nutcracker may also provide a competitive advantage for whitebark pine by carrying seeds longer distances into burned areas than wind typically carries seeds from wind-dispersed species.

Approaches to Restoring Whitebark Pine

In light of the threats facing whitebark pine, various restoration efforts have been undertaken across its range. Some of these approaches include seed collection and planting programs, and habitat enhancement programs. Whitebark pine cones are expensive and difficult to collect, as cones must be caged to prevent foraging damage by Clark's nutcrackers and collected later when cones are ripe. Clark's nutcrackers often cache unripe seeds that may not germinate for several years. Habitat enhancement programs for whitebark pine typically consist of prescribed fire or silviculture treatments that create openings in the forest canopy to reduce local competition levels and create suitable caching sites for Clark's nutcrackers. Sufficient levels of whitebark pine must be maintained on the landscape for Clark's nutcrackers to continue to select and cache whitebark seeds. Although Clark's nutcrackers may travel great distances with seeds and are believed to favour burned-over areas for seed-caching, recruitment success on burned areas is still limited by local availability of seeds. In surveys of historic wildfires in the Rocky Mountains and North Cascades, Moody (2006) found that recruitment was not always greater on burned sites and that seed source variables significantly influenced regeneration success.

This poster reports on two restoration efforts undertaken in 2007. At the northernmost limit of this species' range, Ministry of Environment and Ministry of Forests and Range staff in the Fort St. James Forest District undertook a joint, in-house cone collection project that contributed 145 000 seeds to the Provincial Tree Seed Centre (up from approximately 3000 seeds). Thirty-nine climbable trees that exhibited a low number of blister rust cankers and no mountain pine beetle attack were selected for collection and provenance trials. Each parent tree was mapped and seedlots were separated by parent. This contribution of seed from the current northern range limit of whitebark pine provides a much-needed seed bank for future restoration activities. Seed has already been committed to a University of Northern British Columbia mycorrhizal study and a co-ordinated seedling production trial. This project contributed a significant amount of seed to an almost non-existent seed bank, and provided a valuable opportunity to increase awareness and understanding about a threatened species. The in-house collection efforts by a wide variety of district staff also resulted in team-building, enthusiasm, and strengthened inter-Ministry relationships.

In Manning Provincial Park, a restoration program was implemented that consisted of seed collection and planting and the development of a burn plan. In the seed collection program, 360 cones were caged on 30 phenotypically rust-resistant parent trees, resulting in an eventual yield of 18 500 seeds. Again, each parent tree was mapped and seedlots separated by parent. The seeds were split among three projects with 10 500 going to the restoration planting program, 5000 to provenance trials, and the remaining 3000 to seedling production trials.

The restoration planting program consisted of planting seeds in permanent 5.64 m radius monitoring plots. Seeds were planted at three general locations throughout the park, with several ecologically different sites planted at each location. Within ecologically homogeneous habitats, monitoring plots were established on transects or in clusters. A total of 8000 seeds were planted in 40 monitoring plots, with 2500 seeds planted outside of the plots on comparable habitats.

Within each monitoring plot, 30 seed caches were established, with each cache consisting of six seeds from a common parent. The location of each cache was mapped within each plot to allow for the monitoring of recruitment success over time and to possibly identify parent trees best suited to seed collection for future restoration programs.

The prescribed burn plan was intended to create open areas for regeneration as well as maintain all seed trees and advance regeneration onsite. During this preliminary phase, potential burns sites were selected by locating whitebark pine stands with poor self-replacing potential and feasible access for pre-burn sampling and fuel treatments. Before implementing the burn plan, it was recommended that seed trees and advanced regeneration be mapped on each site to determine which type of burn would best maintain whitebark pine onsite. After whitebark pine mapping, recommended burns may range from mixed severity (i.e., where whitebark is spread throughout the stand) to stand-replacing (i.e., where whitebark is isolated on nearby ridges) depending on the spatial distribution of whitebark pine in the stand. Regardless of the prescribed burn severity, the establishment of an unburned control area and permanent monitoring plots was recommended.

Recommendations

These initial seed collections for restoration efforts resulted in the following recommendations.

- Secure multi-year funding for seedling production and planting.
- Continue seed collections throughout British Columbia for gene conservation measures.
- Expand seed and seedling planting programs throughout the provincial range of the whitebark pine.
- Annually monitor seeds planted in 2007.
- Reduce or eliminate "bycatch" harvesting of whitebark pine to protect future seed supply.
- Emphasize whitebark retention in prescribed burn planning.

References

B.C. Conservation Data Centre. 2008 . Conservation status report: *Pinus albicaulis*. B.C. Ministry of Environment. URL: *http://a100.gov.bc.ca/pub/eswp/*

Campbell, E.M. and A. Carroll. 2007. Climate-related changes in the vulnerability of whitebark pine to mountain pine beetle outbreaks in British Columbia. Nutcracker Notes 12:13–15.

Hamman, A. and T. Wang. 2006. Potential effects of climate change on ecosystem and tree species distribution in British Columbia. Ecology 87(11): 2773–2786.

Moody, R.J. 2006. Post-fire regeneration and survival of whitebark pine (*Pinus albicaulis* Engelm.). MSc thesis. University of British Columbia, Vancouver, B.C.

Zeglen, S. 2002. Whitebark pine and white pine blister rust in British Columbia, Canada. Canadian Journal of Forest Research 32:1264–1274.

Popular Summary

Thermal modification: Value-added wood drying process to imitate cedar

Dallin L. Brooks[1]

Presentation Abstract

Thermal modification can turn blue-stained lodgepole pine into a cedar substitute. This chemical-free drying process uses a stainless steel kiln saturated with steam to heat wood up to 190–210°C. The chemical and physical characteristics of the wood change as the heat and steam lower the permeability of the wood by crystallizing the hemicellulose. The effects of the lower permeability on blue-stained wood are increased stability, improved durability, and darker colour. These attributes effectively emulate cedar. Over the last 15 years, thermally modified wood has been sold in the European market as a substitute for cedar decking, siding, sauna panelling, and other products. The same opportunity exists in North America to allow thermally modified blue-stained pine to be sold as a cheaper substitute to cedar. Thermal modification offers cheaper products to the same markets, using high-quality, low-cost local species and gives British Columbia manufacturers a competitive advantage again.

KEYWORDS: *blue-stain, cedar, drying, durability, innovative technology, new opportunities, thermal modification, value-added.*

Contact Information

1 TekmaHeat Canada, Jartek, 2665 East Mall, Vancouver, BC V6T 2C8. Email: d.brooks@tekmaheat.com

Brooks, D.L. 2008. Thermal modification: Value-added wood drying process to imitate cedar. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):159–162. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Background

The enhancing of wood properties for commercial applications is typically done through the creation of engineered wood products or chemical impregnation. However, other methods of changing chemical and physical properties of solid wood are garnering interest. These other methods include acetylation, furfurylation, enzymatic treatments, and thermal modification.

Thermal modification of solid wood is accomplished by heating the wood to temperatures high enough to crystallize some of the hemicellulose, which reduces the amount of water-absorbing hydroxyl groups (Finnish ThermoWood Association 2003). This change begins around 180°C, a temperature unattainable without the use of a medium to displace the oxygen, as wood is flammable without a spark at 150°C. The patented ThermoWood process uses steam to displace the oxygen inside the chamber, which prevents the wood from burning at the high temperatures. Developed in Finland by their technical research centre VTT, the Finnish treatment for thermal modification is the most successful commercial method. Some reasons for this success are that the Finnish ThermoWood Association capitalizes on the chemical-free aspect in a market striving to go "green" and on the ability to manufacturer larger chamber capacity for better economies of scale.

The Finnish ThermoWood Association has patented the following three-phase thermal modification process (Figure 1).

Phase 1 – High Temperature Drying

- Heat and steam raise temperature to 100°C
- Moisture content of wood reduced to approximately 0%

Phase 2 – High Intensity Heat Treatment

- Temperature increased from 180°C to 210°C for 2–3 hours (temperature and time depend on end-use application)

Phase 3 – Cooling and Moisture Conditioning

- Temperature decreased with water spray to increase moisture content to a usable 4–8%

The high temperature does not just affect the hemicellulose in the wood: depending on the temperature, some of the lignin is also crystallized, and all the extractives in the wood are removed through the surface. Thus, the thermal modification process creates a permanent change in the chemical composition of the wood. When compared to traditionally kiln-dried wood of the same species, thermally modified wood has an equilibrium moisture content 40–50% lower (Finnish ThermoWood Association 2003).

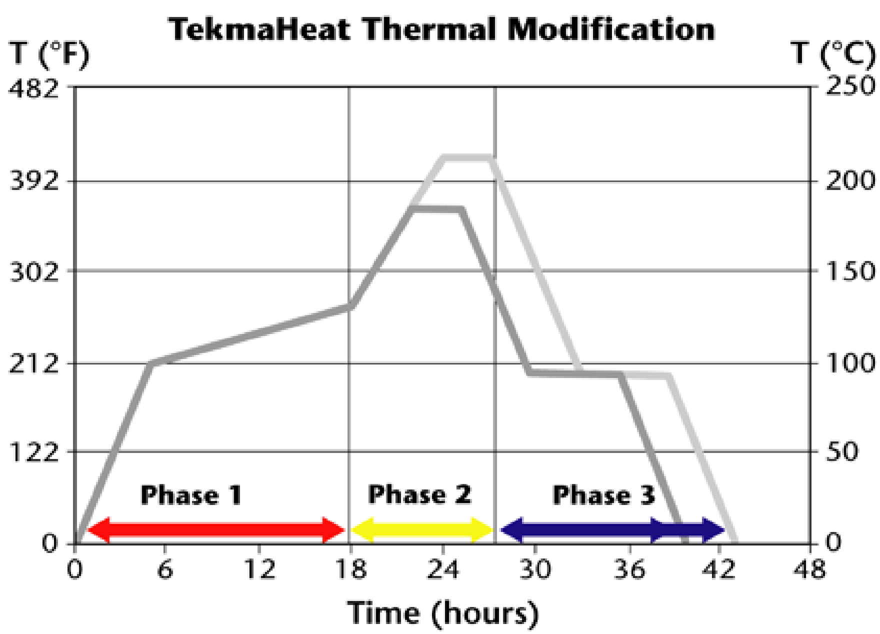

FIGURE 1. Three-phase thermal modification process patented by the Finnish ThermoWood Association.

Discussion

Initially, products developed by thermal modification manufacturers where seen as substitutes for chemically impregnated wood. To compete with chemical preservatives, thermal modification requires heating the wood above 230°C, which reduces its workability. This is because the reduced amount of fungi-susceptible material correspondingly increases the wood's brittleness (Finnish ThermoWood Association 2003). Although some of the mentality surrounding competition with chemical preservatives still exists, manufacturers have largely relaxed their claims for complete biological durability and have aimed instead for the naturally durable species and improved stability.

Tests have shown a moderate increase in durability with temperatures as low as 180°C (Finnish ThermoWood Association 2003). The thermally modified softwoods are comparable to cedar in durability and colour at 180–200°C. In the case of lodgepole pine killed by the mountain pine beetle, blue-stain can be completely concealed through the darkening in colour achieved by thermal modification (Value to Wood Program 2003).

Engineered and glued wood products are generally regarded as more stable because they do not warp, cup, shrink, or swell as much as solid wood. The high temperature and steam used in thermal modification relieve the stresses in the wood. For this reason, solid wood that is thermally modified may cup, but after planing to remove any initial changes, the wood will not cup or warp again. If an edge-glued or finger-jointed product is desired, thermally modified wood can be glued in the same way as non-treated wood.

At its simplest level, the changes to solid wood by thermal modification are darker colour, lower moisture content, and permeability. The effects of these changes on wood products are increased dimensional stability, improved biological durability, and improved paint performance over the original wood. The reduced moisture permeability lowers the finishing and adhesive requirements and improves performance based on the decreased tangential and radial swelling. Sap stain is also eliminated by removing the extractives from the wood.

European manufacturers of thermally modified wood have gained a valuable understanding of heat treatment (e.g., the negative effects of higher temperatures on the workability of the wood and the need to use high-grade material). If North American manufacturers avoid the mistakes and build upon the successes of the European manufacturers, they could create a commercially viable market for thermal modification as well.

To be commercially viable, thermal modification needs a market with a substantial profit margin to compensate for the high capital costs of the process. Such a market exists because of the price gap between western redcedar and spruce, pine, or fir (S-P-F). According to Random Lengths, the price for standard or better cedar 2×4s is $815/Mbf; the price for S-P-F is $230/Mbf (Random Lengths 2007). This price gap comes from the many issues currently plaguing western redcedar producers including reliability of raw materials and quality of second-growth wood. However, many issues currently plague S-P-F producers, including reliability of raw materials, quality of mountain pine beetle-killed lodgepole pine, and low housing starts.

Costs for thermally modifying wood vary greatly, from $50 to $140/Mbf, depending on the technology used and the volume of the operations. Typical chamber volumes range from 2 to 10 million board feet (MMbf) per year. Because it is a new technology, it is hard to know how successful thermal modification can be in terms of annual production. In 2001, production capacity was estimated at 70 MMbf, with an increase to 112 MMbf projected by 2003 (Holger 2002). Yet, in 2004 worldwide production for thermal modification was estimated at 21–42 MMbf per year (Homan 2004). In 2006, the Finnish ThermoWood Association reported that its members had an annual capacity of 42 MMbf (Finnish ThermoWood Association 2006). Annual sales production for ThermoWood also increased 30% in 2006 (Finnish ThermoWood Association 2006).

Environmental concerns and increased competition from foreign imports are increasing issues, especially as foreign importers offer cheap substitutes for North American products. Using thermal modification, Canadian and American wood manufacturers have the opportunity to offer less-expensive substitutes of their own, with an environmentally friendly label. The price differential between cedar and S-P-F of $585/Mbf minus the estimated cost of thermal modification at $140/Mbf leaves a gap of $435/Mbf for thermal modification producers to exploit.

Yet, barriers exist for thermal modification in North America. The high capital cost is foremost, especially as the industry is impeded by low investment capital due to low returns. Maximizing capacity requires pre-drying, which increases handling costs and sticker consumption. Additionally, the quality of the wood is a consideration as heat treatment does not remove the knots, wane, and checks already present. Tear-out is not uncommon and UV protection is required to keep it from fading. Although rot and insect problems are significantly reduced by thermal modification, they are not eliminated.

Conclusion

European producers of thermally modified wood have developed five main product markets over the last decade: siding and cladding, decking, hardwood flooring, saunas and wall panelling, and specialties. The success of thermal modification originates from allowing lower-cost species to compete with naturally durable and higher-cost species, such as cedar and exotic hardwoods in these markets.

Commercialization of thermal modification is increasing, based on strong European market experience and a substantial number of technology providers. Thermal modification offers cheaper products to the same markets, using high-quality, low-cost local species. Nevertheless, the high capital cost will be prohibitive to many investors.

In many ways, North American wood markets will be able to follow the European model to integrate thermal modification into their production. For siding, cladding, and decking, thermal modification provides an inexpensive substitute for western redcedar that is a better option than regular S-P-F due to the durability and stability improvements and the elimination of resin bleed.

The development of thermal modification in North America is unlikely to begin with large corporate sawmills until the market is creating big demand or partnerships/subsidiaries take interest. Mid-sized, value-added manufacturers and start-up companies are well situated to capitalize on the market potential of thermally modified wood. Many of these mid-sized companies will be siding and decking manufacturers. Other value-added manufacturers will invest to compete with imports and create less expensive substitutes. Even cedar manufacturers can diversify with thermal modification to offer their distributors lower-cost goods, and not rely exclusively on variable cedar availability. Entrepreneurs who are looking for new opportunities will see a chance to provide specialty products to an industry that always needs a new colour or a new line. Start-up companies will fuel an industry that is trying to rediscover its competitive advantage.

The opportunity exists, and the path to follow has been laid out, if North American wood manufacturers will seize it. Thermal modification can aid them to regain the competitive advantage over foreign imports.

References

Brooks, D. 2007. Commercialization of thermal modification. Canadian Wood Preservers Annual General Meeting, October 2007, Quebec City, Que.

Finnish ThermoWood Association. 2003. ThermoWood handbook. Helsinki, Finland.

________. 2006 ThermoWood production statistics. Helsinki, Finland.

Homan, W.J. 2004. Wood modification: State of the art 2004. SHR Timber Research, Wageningen, The Netherlands.

Militz, H. 2002. Heat treatment technologies in Europe: Scientific background and technological state-of-art. Conference Proceedings, Enhancing the durability of lumber and engineered wood products. Madison, Wis.

Random Lengths Publications Inc. 2007. Lumber price guide. Random Lengths 63(38).

Value-to-Wood Program. 2003. Technology profile TP_03_01E: Thermally modified wood. URL: *http://www.valuetowood.ca/imports/pdf/en/tech_profiles/TP-03-01E_TLihra_English.pdf*

Popular Summary

Development of mountain pine beetle wood-plastic composites

Feng-Cheng Chang[1], Azzeddine Oudjehane[2], and Frank Lam[3]

Presentation Abstract

Aiming to optimize the use of the available mountain pine beetle (MPB) fibre and particles, wood-plastic composite products were developed in this study. The feasibility of utilizing beetle-killed lodgepole pine to manufacture wood-plastic composites (WPC) was assessed within the study's framework. Several flour mesh sizes (20, 40, 60, and 80 mesh) and wood contents (40, 50, and 60%) were used in combination with high-density polyethylene (HDPE) to make strip-like specimens. These samples were then tested in simple tensile experiments. Extrusion and injection moulding processes were also performed to fabricate other test samples and prototype end products. The preliminary bending and tension tests of the prototype products have shown great potential, particularly for the injection moulding wood-HDPE composites. Indeed, the latter prototype product displayed improved properties over a commercial product also tested for benchmark comparison.

KEYWORDS: *lodgepole pine, mountain pine beetle, tension and bending tests, wood-plastic composites.*

Contact Information

1 Wood Science, University of British Columbia, 2424 Main Mall, Vancouver, BC V6T 1Z4.
Email: apec330@interchange.ubc.ca

2 Wood Science, University of British Columbia, 2424 Main Mall, Vancouver, BC V6T 1Z4.
Email: oudjehane@forestry.ubc.ca

3 Wood Science, University of British Columbia, 2424 Main Mall, Vancouver, BC V6T 1Z4.
Email: frank.lam@interchange.ubc.ca

Chang, F.-C., A. Oudjehane, and F. Lam. 2008. Development of mountain pine beetle wood-plastic composites. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):163–166. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Background

The wood-plastic composites (WPC) industry has experienced rapid growth in North America with market expansion. With a current market estimated at US $1 billion, the demand for wood-plastic in residential applications is expected to increase by 20% over the next 5 years. Within this framework, applications for wood-plastic composites using trees killed by mountain pine beetle (MPB) are extremely wide. These range from decking products to lawn furniture, playground equipment, and industrial applications such as railings for marinas and bumpers for shipyards. Development of such products should be accompanied by the acquisition of a full understanding of the structural properties of WPC and the exploration of methodologies for producing new materials.

Wood-plastic composites are typically made using 30–60% wood filler. Using wood flour as a filler reduces raw material costs and improves the stiffness and dimensional stability of the product over a range of temperatures with minimal weight increase (English *et al.* 1997). When appropriate coupling agents are added to increase fibre-matrix compatibility and adhesion, mechanical properties can be improved (English *et al.* 1996; Lu *et al.* 2000).

Wood flour is made by grinding post-industrial material, such as planer shavings, chips, and sawdust, into a fine, flour-like consistency (Stark 1997). Wood fibre is available from both virgin and recycled sources, including pallets, demolition lumbers, and old newsprint (Hwang 1997; Lu *et al.* 2000; Clemons 2002). Wood from small-diameter trees and underutilized species can also be used.

Three typical forming methods for WPC include:

1. extrusion to make a continuous profile of the desired shape (forcing molten composite through a die) (Figure 1);
2. injection moulding (forcing molten composite into a cold mould); and
3. compression moulding (pressing molten composite between mould halves).

In addition to wood, many particle and fibre types have been investigated such as wheat, kenaf, cornstalk, and jute (Rowell 1996; Youngquist *et al.* 1996; Caulfield *et al.* 1998; Chow *et al.* 1999). English *et al.* (1996) investigated the difference between wood and mineral fillers in composites and indicated that wood filler could reduce the specific gravity of composites. This constitutes a significant advantage in packaging and transportation applications. Consequently, WPC could be a potential value-added application for wood attacked by MPB. A feasibility assessment of using MPB fibre in the manufacture of wood-plastic composites is presented in this study.

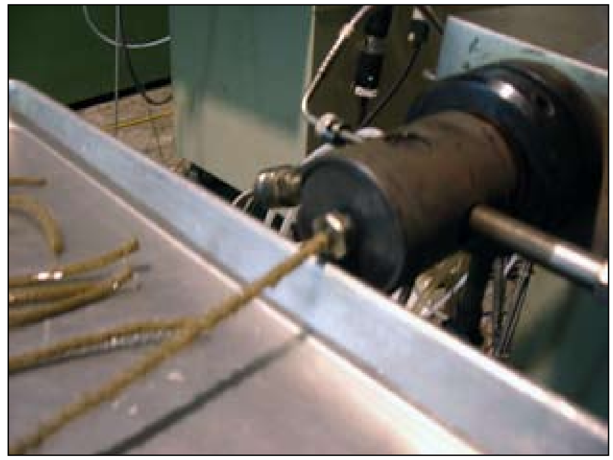

FIGURE 1. Extrusion processing of wood-plastic composites.

Methods

To produce WPC prototype samples, chips were obtained from logs harvested in the Vanderhoof area of British Columbia. High-density polyethylene (HDPE), the plastic material commonly used in commercial WPC products, was selected as the matrix. The specimens were produced with various formulations of wood content (40, 50, and 60%) and the corresponding amount of plastic by weight. Wood flours were prepared by grinding chips small enough to pass through four mesh screen sizes (20, 40, 60, and 80 mesh screens). To study the natural compatibility between the MPB wood and HDPE, no additive was used in this study.

The constituents were mixed dry by hand and then extruded through a single-screw extruder (CWB production systems, PL2000 and FE2000). The mixture of MPB wood and HDPE was fed into the hopper of the extruder. Temperatures in three sections of the four-section extruder barrel reached 180°C and 185°C in the other section of the barrel. A screw revolution of 60 rpm produced the extrudate through an annular die; a sheet die was used for further specimen formation

FIGURE 2. Preliminary tension test of strips made from wood-plastic composites containing MPB-killed wood.

FIGURE 3. Set of WPC injection moulding specimens containing MPB-killed wood.

and mechanical tests. The selected formulation was processed using injection moulding to make specimens. A commercial product was used for a benchmark comparison. The extrusion process of the MPB wood-plastic prototype was undertaken at CST Innovations Ltd. in New Westminster, B.C.

Three separate tests were undertaken to assess the formulation chosen for the WPC prototypes:

1. Thirty replicates of WPC strip-like extrudate with a diameter of 2.7 mm were subjected to uniaxial tension tests (Figure 2).
2. Fifteen specimens of WPC mixture moulded by the extruder with a sheet die to form 2.9 mm thick sheet specimens were subjected to uniaxial tension tests.
3. Bending and tension tests of the WPC specimens prepared using injection moulding.

Several sets of samples were processed as shown in Figure 3.

Results

The preliminary tests conducted to determine the appropriate concentration of several formulations show that the 60 wood flour mesh size and 40% wood content resulted in the highest strength of the WPC specimen. The experiments also showed that the MPB WPC prototype products had comparable properties to the commercial products tested. When compared to the commercial product, the injection moulding MPB wood-HDPE composite had a higher tensile strength and a comparable bending strength, but lower modulus of elasticity.

These results illustrate the potential of using MPB-killed wood to manufacture WPC. This study also highlights that the simple tension testing of strip-like extrudate may be acceptable for a preliminary selection of formulations in the development of MPB wood-plastic prototypes.

References

Caulfield, D.F., N. Stark, D. Feng, and A.R. Sanadi. 1998. Dynamic and mechanical properties of the agro-fiber based composites. *In* Progress in woodfibre-plastic composites: Emergence of a new industry. Materials and Manufacturing, Mississauga, Ont.

Chow, P., T.C. Bowers, D.S. Bajawa, J.A. Youngquist, J.H. Muehl, N.M. Stark, A. Krzysik, and L. Quang. 1999. Dimensional stability of composites from plastics and cornstalk fibers. *In* Proceedings, 5th International Conference on Wood Fiber-Plastic Composites, May 26–27, 1999. Forest Products Society, Madison, Wis. pp. 312–313.

Clemons, C. 2002. Wood-plastic composites in the United States: The interfacing of two industries. Forest Products Journal 52(6):10–18.

English, B., C.M. Clemons, N. Stark, and J.P. Schnieder. 1996. Waste-wood derived fillers for plastics. U.S. Department of Agriculture Forest Service, Forest Products Laboratory, Madison, Wis. General Technical Report No. FPL-GTR-91. pp. 282–291.

English, B., N. Stark, and C. Clemons. 1997. Weight reduction: Wood versus mineral fillers with polypropylene. *In* Proceedings, 4th International Conference on Wood Fiber-Plastic Composites. May 12–14, 1997. Forest Products Society, Madison, Wis. pp. 237–244.

Hwang, G.S. 1997. Manufacturing of plastic/wood composite boards with waste polyethylene and wood particle. Taiwan Journal of Forest Science 12(4):443–450.

Lu, J.Z., Q. Wu, and H.S. McNabb, Jr. 2000. Chemical coupling in wood fiber and polymer composites: A review of coupling agent and treatments. Wood and Fiber Science 32(1):88–104.

Rowell, R.M. 1996. Composites from agri-based resources. *In* Proceedings, Use of recycled wood and paper in building applications. R.H. Falk (editor). Forest Products Society, Madison, Wis. Proceedings No. 7286, pp. 217–222.

Stark, N.M. 1997. Effect of species and particle size on properties of wood-flour-filled polypropylene composites. *In* Proceedings, Intertech Conference on Functional Fillers. December 8–10, 1997, San Diego, Calif.

Youngquist, J.A., A.M. Krzysik, B.W. English, H.N. Spelter, and P. Chow. 1996. Agricultural fibers for use in building components. *In* Proceedings, Use of recycled wood and paper in building applications. R.H. Falk (editor). Forest Product Society, Madison, Wis. Proceedings No. 7286, pp. 123–124.

Popular Summary

Development of mountain pine beetle wood-cement composites

Feng-Cheng Chang[1], Azzeddine Oudjehane[2], and Frank Lam[3]

Presentation Abstract

Processing of the wood and logs killed by mountain pine beetles (MPB) typically generates a large volume of fines and lower-quality wood particles. The use of fines and residual fibres to develop other new composite products based on MPB wood will be a key to the overall viability of the forest products sector. One product that can utilize the available fibre is a wood-cement composite made from beetle-killed pine fibre, cement, and other additives. In this study, several configurations of cement-bonded boards were considered and their properties investigated. Mountain pine beetle fibre and particles were sourced from four different types of lodgepole pine. Two different log sizes and two different years since tree death (3 and 5 years) were considered. The MPB wood fibre was combined with two types of cement and additives at various ratios of wood to cement and water. A range of additive conditions was also studied to identify potential formulations for prototype development. Mechanical and physical tests were conducted to examine the quality of MPB wood-cement prototype products. Results of the preliminary tests show that the 3-years-since-tree-death wood particles from small logs (diameter < 28 cm) with either type of cement and additive would be the best formulation. Other formulations also show comparable mechanical and physical properties to those of other cement-bonded products.

KEYWORDS: *cement-bonded particleboard, lodgepole pine, mountain pine beetle, Portland cement, wood-cement composites.*

Contact Information

1 Wood Science, University of British Columbia, 2424 Main Mall, Vancouver, BC V6T 1Z4.
Email: apec330@interchange.ubc.ca

2 Wood Science, University of British Columbia, 2424 Main Mall, Vancouver, BC V6T 1Z4.
Email: oudjehane@forestry.ubc.ca

3 Wood Science, University of British Columbia, 2424 Main Mall, Vancouver, BC V6T 1Z4.
Email: frank.lam@interchange.ubc.ca

Chang, F.-C., A. Oudjehane, and F. Lam. 2008. Development of mountain pine beetle wood-cement composites. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):167–169. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Background

The mountain pine beetle (MPB) (*Dendroctonus ponderosae* Hopkins.) is currently the most destructive biotic agent of mature pine forests in western North America. Processing dry MPB-killed trees can lead to the generation of more fine material and residues compared to healthy, green logs. Thus, there is a need to investigate alternative value-added wood-based products that can make use of these processing residues. The chemical components of MPB fibre, with its lower sugar and hemicellulose content (Woo *et al.* 2005), may be regarded as a potential advantage in producing wood-cement composite products.

Cement-bonded board combines the properties of two important materials: cement and any fibrous material such as wood or agricultural residues. It is either made of strands, flakes, chips, particles, or fibres of wood, or of some other agricultural residue bonded with ordinary Portland cement (Eusebio 2003). A number of variables influence the properties of the final product, including: wood species and its physical and chemical characteristics; particle size and geometry; cement type; any additives; proportions of wood, water, and cement; temperature of the environment; and time allowed for setting (Jorge *et al.* 2004).

In previous work, the compatibility of MPB-attacked wood and wood-cement composites was evaluated with a hydration test that is commonly used to predict the general inhibitory properties and feasibility of the raw material before the manufacture of cement-bonded boards. With a high hydration rate, MPB wood may be a potential raw material for wood-cement composites as long as it is treated with appropriate additives (Chang and Lam 2008). However, laboratory hydration test results may not be directly applied in real product processing because different wood/cement ratios are used in lab-tested samples and in commercial products. The objective of this study was to fabricate a cement-bonded particleboard and evaluate its physical and mechanical properties.

Methods

For this study, four types of lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.) chips were obtained from MPB-killed trees in the Vanderhoof area of British Columbia:

1. small logs (diameter at butt < 28 cm) from 3-years-since-death trees (3S),
2. large logs (diameter at butt > 28 cm) from 3-years-since-death trees (3L),
3. small logs from 5-years-since-death trees (5S), and
4. large logs from 5-years-since-death trees (5L).

FIGURE 1. Cement-coated particles distributed in the form mould.

The wood particles were processed in a Willey mill with materials passing through a 2-mm screen.

To compare the effects of different cement types, two types of Portland cement were used. Type I cement is typically used in the wood-cement industry. Type III is chemically similar to type I, but is ground finer. In addition, two common additives, magnesium chloride ($MgCl_2$) and calcium chloride ($CaCl_2$), were used to study the effects of different additives and contents.

Composite boards (305 × 305 × 15 mm) were created using a wood to cement ratio of 1:3, and a water to cement ratio of 0.6:1 (Figure 1). The additives (3% of cement weight) were used to improve the hydration reaction of cement. The moulded mat was pressed at ambient temperature using a hydraulically operated press (Figure 2). The pressed mats were kept under constant pressure for 24 hours. After 24 hours, the boards were de-clamped, stacked, and conditioned for several weeks to allow the composites to cure and increase in strength (Figure 3).

After curing, each cement-bonded particleboard was cut into the various dimensions for different bending and compression experiments. Properties of bending, compression, thickness-swelling, and water absorption were tested in accordance with the D1037 method of the American Society for Testing and Materials (ASTM).

FIGURE 2. Press mat at ambient condition for 24 hours.

FIGURE 3. The cured cement-bonded particleboards.

Results

The mechanical bending and compression strength tests showed that the MPB wood-cement composites had comparable properties to wood-cement products tested in previous published studies. However, the MPB-killed wood's lower hemicellulose and sugar content is beneficial for manufacture.

Based on the bending and compression results, the formulation of 3S logs with type III cement and $MgCl_2$ resulted in the highest strength value, although the same formulation with $CaCl_2$ also had a similar strength level. Moreover, cement types had no significant effect on final properties. In addition, MPB wood-cement prototype products subjected to water-soaking were dimensionally stable, but the volume of water adsorption was noticeable.

Curing time of MPB wood-cement boards after pressing (which was not accounted for in this study) may affect the strength of products. A more efficient processing method should be investigated to improve the production rate; for example, addition of carbon dioxide during pressing could reduce the pressing time 8–24 hours to less than 5 minutes. Other properties of MPB wood-cement products should also be considered in a full feasibility assessment of prototype production. Properties such as durability under bio-deterioration conditions as well as environmental attack, and fastener-holding ability are vital with respect to the application of wood-cement products. Fire resistance, and sound absorption and insulation are other common properties of wood-cement products that require testing.

References

Chang, F.C. and F. Lam. 2008. Suitability of fibres from mountain pine beetle attacked wood in wood-cement composite materials. Forest Products Journal 58(3):85–90.

Eusebio, D.A. 2003. Cement bonded board: Today's alternative. Paper presented at a technical forum in celebration of the 21st PCIERD anniversary, DOST held at EDSA Shangri-La, EDSA, Pasig City.

Jorge, F.C., C. Pereira, and J.M.F. Ferreira. 2004. Wood-cement composites: A review. Holz Roh Werkst 62:370–377.

Woo, K.L., P. Watson, and S.D. Mansfield. 2005. The effect of mountain pine beetle attack on lodgepole pine wood morphology and chemistry: Implications for wood and fibre quality. Wood and Fiber Science 37(1):112–126.

Popular Summary

Bending behaviour of thick laminated mountain pine beetle wood plates with different connections

Yue Chen[1], Azzeddine Oudjehane[2], and Frank Lam[3]

Presentation Abstract

Developed and introduced in Europe during the early 1990s, engineered wood products in which short-length, low-grade members are cost-effectively glue laminated into thick plates are marketed as high-value structural wood products. Typical beetle-killed pine logs are extremely dry with heavy checks. Processing these logs results in a large volume of degrade material that is either chipped or used for non-structural applications. The cross-lamination of low-grade beetle-killed wood can convert the material into high-value structural wood products, adding value to a large amount of wood affected by the mountain pine beetle (MPB). Within the framework of this study, three-dimensional finite-element models and simulations were developed using a commercial software package (ANSYS®) to analyze the bending behaviour of three-layer cross-laminated wood plates. Several layout configurations and connections, such as glue or nails, were considered. To determine the properties of MPB wood to be used in the manufacturing of prototype laminated plates, compression tests parallel to grain were conducted. Six specimens of prototype thick plate composites using both nail and glue connections were manufactured at the University of British Columbia. The prototype plates were tested with bending loads applied to the top surface of the products. Both the experimental data and the numerical simulation were in good agreement. As expected, the value-added MPB end product displayed strong properties.

KEYWORDS: *bending test, cross-laminated thick wood plate, finite-element models.*

Contact Information

1 Wood Science, University of British Columbia, 2424 Main Mall, Vancouver, BC V6T 1Z4.
Email: yuechen@interchange.ubc.ca

2 Wood Science, University of British Columbia, 2424 Main Mall, Vancouver, BC V6T 1Z4.
Email: oudjehane@forestry.ubc.ca

3 Wood Science, University of British Columbia, 2424 Main Mall, Vancouver, BC V6T 1Z4.
Email: frank.lam@interchange.ubc.ca

Chen, Y., A. Oudjehane, and F. Lam. 2008. Bending behaviour of thick laminated mountain pine beetle wood plates with different connections. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):170–173.
URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Background

The concept of cross-laminated thick wood plate products was developed in Europe during the early 1990s. A typical cross-laminated plate consists of bonded lumber that is glued with a durable adhesive bond, ensuring the structural components are dimensionally stable and resistant to warping. The plate can be manufactured in three, five, seven, and multilayer composites with different component thicknesses. Technically, production of any overall thickness of end-product plate is possible by combining layers of different lumber thickness. It is also possible to apply engineered wood products, such as oriented strand board or plywood, to the plate by surface bonding. The cross-laminate structure guarantees integral stability of the plate, minimizing problems such as shrinkage or swelling.

Cross-laminated plates provide an innovative massive building system for single and multi-family residential dwellings; multistorey residential, commercial, and industrial buildings, or special applications in structural timber constructions. The cross-laminated plates are mostly used for load-bearing and stiffened exterior and interior walls, floors, ceilings, and roof elements. Elements that are prefabricated with ready-made openings for windows, doors, and cable ducts can be delivered directly to the building site for step-by-step immediate assembly. Cross-laminated plates have been widely used in Austria, Germany, and Switzerland in numerous residential projects. On-site assembly minimizes construction time and costs. The product is versatile and perfectly combinable with other construction materials. As a result of its excellent load distribution properties in both directions, the plate presents no limitations for architectural, residential, or utility building projects. This is a significant reason for its increasing use in the construction of detached and multi-tenant residential properties or in the construction of commercial and industrial premises. In addition, its enormous load-bearing and rugged properties ensure the increasing popularity of this high-quality construction product in the construction of bridges, carports, ancillary buildings, and wood/concrete composite ceilings.

The most significant advantages of the thick cross-laminated wood plate include:

- Suitability for the construction of single and multi-storey residential, commercial, and industrial buildings.
- Greater static load-bearing capacity and integral stability ensured by the cross-laminated vertical and horizontal layers.
- A long-lasting construction of stable value and a favourable price–performance ratio.
- Simpler on-site processing and minimum construction and assembly time.
- A high thermal insulation allowing for airtight construction and optimized energy balance when compared to other types of wood construction.

To illustrate the current trend of ecobuilding construction in Europe, the world's tallest (nine-storey) wooden residential building in Hackney, London, was designed using a thick-laminated plate system (Skyscrapernews.com 2008).

In this study, a comprehensive three-dimensional finite-element model was established using the commercial software package ANSYS®. The simulation model enables the prediction of the mechanical behaviour of thick laminated wood plates used in floor applications. Several plate configurations with a different number of layers, thicknesses, and angles of layout were examined. A three-layer cross-laminated plate configuration was finally chosen for the experimental validation study using different types of connections of the wood members (e.g., glue and nails). The experimental analysis also provided the opportunity to develop prototype products using lumber milled from trees killed by the mountain pine beetle (MPB). Laboratory scale and full-size thick MPB wood plate prototypes were manufactured, and then tested for load-bearing capacity in a four-point bending test.

Finite-element Modelling and Experimental Study

The three-layer cross-laminated wood plate that was chosen for prototype product development consisted of adjacent layers, typically 38 mm × 89 mm wood members placed side by side without any connection in between. These layers were perpendicular to each other.

The simulation analysis was defined according to the following parameters.

- A three-dimensional structural solid element SOLID45, which is defined by eight nodes having three degrees of freedom at each node, was chosen to model the plate.
- A four-point bending test was selected to characterize the static bending behaviour of the system.

- A steel plate was used between each loading point and the specimen. Two small, rectangular areas that were under the steel plates on the top surface of the wood plate were modelled as the bearing area with three-dimensional structural surface effect element SURF154.
- Two types of connections were considered using glue and aluminum nails.
- For the glued plate configuration, it was assumed that the adjacent layers were perfectly bonded together. For the nailed plate, each nail was simulated by a group of longitudinal springs (nonlinear spring element COMBIN39) in three directions. The force–deflection curve of the spring was obtained from nail tests conducted beforehand to obtain the lateral resistance of aluminum nails. Such nails were chosen for their softness and ease to cut using ordinary shop tools. To establish the finite-element model, compression parallel to grain tests were conducted to determine the properties of the MPB wood that was used in the prototype development.

For the validation of the simulation model and prototype product development of MPB thick plates, six laboratory specimens of three-layer cross-laminated MPB wood plates (2.158 m × 1.079 m × 0.099 m) were manufactured at the University of British Columbia. Typical 38 mm × 89 mm #2/Btr MPB dimensional wood lumber in 4.88 m lengths was used. The wood members were randomly selected from lumber packages originating from Quesnel, B.C. The wood members were also planed, sanded, and cut to proper sizes and then assembled to make the thick plates.

Two types of connections were used:

1. Phenol-resorcinol-formaldehyde (PRF) resin was employed for its strong bonding characteristics and water resistance.
2. 6.35 cm aluminum siding nails were selected because of market availability.

During the bending test, the plates were simply supported at the ends. Loading was applied symmetrically at two points along the span (Figure 1). Two transducers were used to measure the plate deflection at the mid-span while the load-deflection relationship was captured through a data acquisition system.

FIGURE 1. Bending test of a three-layer cross-laminated MPB wood plate.

Discussions and Conclusions

Although experimental testing of the lab-manufactured MPB wood plate prototypes enabled the validation of the computer simulation with a good correlation, the distinct properties of the two prototypes should be highlighted.

The glued MPB wood plates deformed linearly with increasing load and brittle failure at the peak load (Figure 2). However, the load displacement relationship appeared to be nonlinear for plates with nail connections because of the flexible characteristics of aluminum (Figure 3). The deflection at failure measured for the nailed MPB wood plates was nearly three times greater than the deflection observed for the glued plates. Nevertheless, the deflection for flooring services normally requires a maximum of 12 mm based on the L/180 deflection limit. Under the same service load, both tested configurations displayed 1.7 mm for the glued plates and 3 mm for the nailed plates. Thus, the engineered MPB wood product is much stiffer and therefore has great potential in construction materials and components sector.

References

Skyscrapernews.com. 2008. Waugh Thistleton get wood in hackney. URL: *http://www.skyscrapernews.com/news.php?ref=1446*

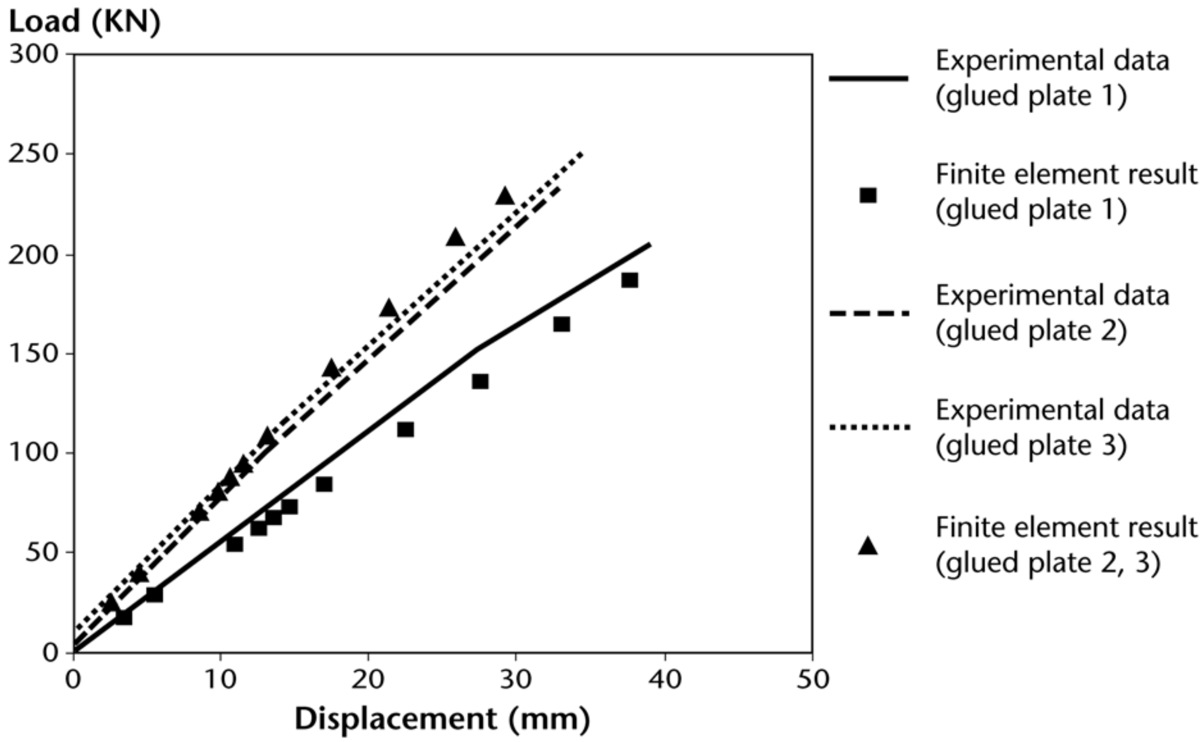

FIGURE 2. Comparison between experimental data and numerical analysis for glued plates.

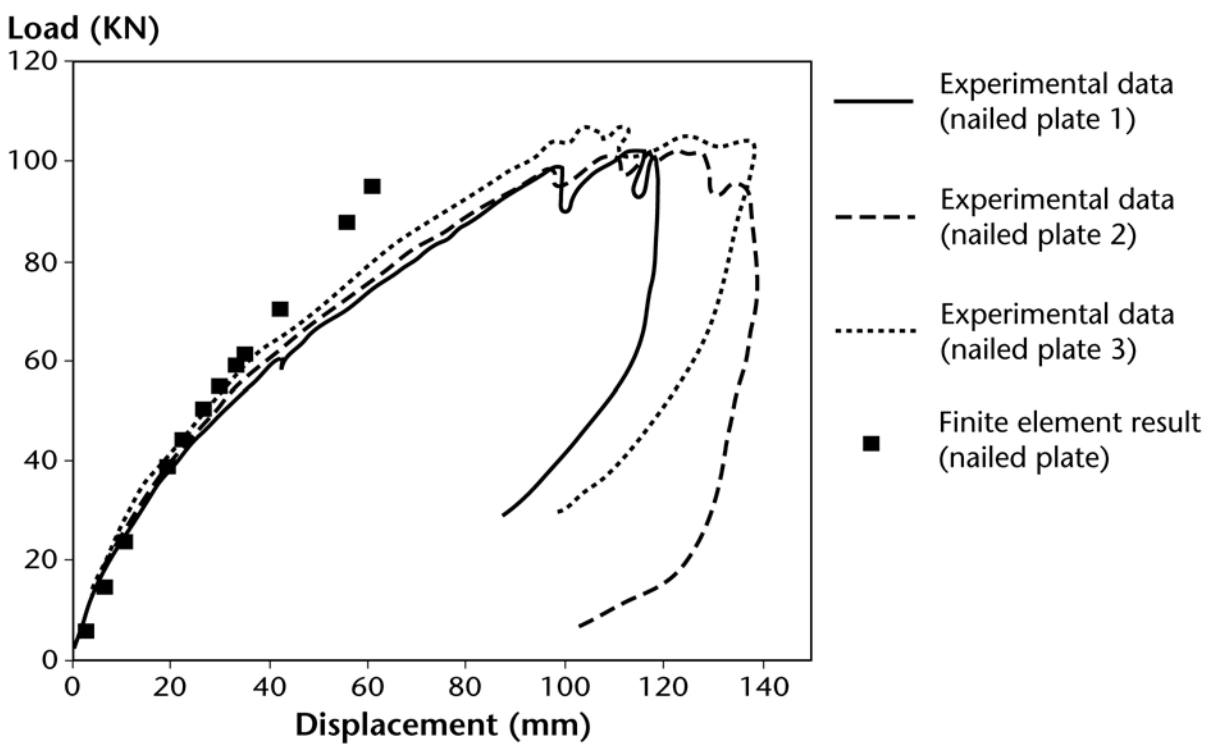

FIGURE 3. Comparison between experimental data and numerical analysis for nailed plates.

Performance of coating systems on mountain pine beetle-affected blue-stained wood

Mohammed Jahangir Chowdhury[1] and Philip Evans[2]

Presentation Abstract

In British Columbia, large volumes of blue-stained lumber from lodgepole pine trees infected by the mountain pine beetle are processed into siding, interior panels, and furniture. The utilization of blue-stained wood for these products is attractive because painting masks the blue-stain. Preliminary research, however, showed that the ability of conventional primers to mask the blue-stain was lost when the painted wood was exposed outdoors. It is not known whether this undesirable property of painted blue-stained lumber is due to the presence of the blue-stain or is simply an inherent characteristic of sapwood. To understand and find a solution to this problem, an experiment was developed that applied a range of finishes to both stained and unstained sapwood and heartwood boards. Coated boards were exposed outdoors in Vancouver, B.C. The colour, gloss, weight, and dimensional change of the painted and exposed boards were monitored. We also carried out a second experiment that examined the effect of blue-stain and coating type on the volumetric swelling of samples in water. The performance of most paints on lodgepole pine is adversely affected by the presence of blue-stain, but acrylic enamel paint appears to be an exception. We therefore recommend its use in preference to other finishes on blue-stained wood.

KEYWORDS: *blue-stained wood, coating systems, performance.*

Contact Information

1 Centre for Advanced Wood Processing, University of British Columbia, 2900–2424 Main Mall, Vancouver, BC V6T 1ZA. Email: mchowdhu@interchange.ubc.ca

2 Centre for Advanced Wood Processing, University of British Columbia, 2900–2424 Main Mall, Vancouver, BC V6T 1ZA. Email: phil.evans@ubc.ca

Chowdhury, M.J. and P. Evans. 2008. Performance of coating systems on mountain pine beetle-affected blue-stained wood. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):174. URL: *http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf*

Abstract

Value-added treatments for post-MPB wood products

Martin Feng[1]

Presentation Abstract

Termite Resistant Framing Lumber – A novel dip-plus-kiln-conditioning process has shown promise to deeply penetrate dry lumber with termiticides without pressure treatment. Termites are a threat to existing markets and an obstacle in many new markets. Termite-resistant framing may provide the solution. FPInnovations–Forintek Division confirmed the dip/kiln process provides deep penetration into Canadian species. Termite tests are now under way in Japan and Hawaii.
Hot Oil-Treated Siding – Thermal treatment improves dimensional stability and decay resistance, and masks blue-stain. Termite resistance does not improve and is only recommended for aboveground use. It may be best for non-structural appearance-grade products such as siding due to reduced strength. Thermal-treated wood fades rapidly outdoors so a coating is needed. Post-MPB lumber takes up too much oil and bleeds. Oil-thermal treatment may be more appropriate for impermeable species, such as spruce.
Glulam Treated with Ammoniacal Copper Quat (ACQ) and Copper Azole (CA) – Glulam is increasingly used for non-residential construction exposed to biological attacks. A treated glulam product that resists biological attacks could expand markets for wood in non-residential construction. Glulam does not take water-borne preservative treatment well after manufacture so it is best to treat the laminating stock. Blue-stained MPB wood can be treated well with ACQ or CA. The colour of ACQ or CA masks the blue-stain very effectively. Roll pressing of preservative-treated laminating stock reduced surface roughness and greatly improved bond quality with phenol-resorcinol-formaldehyde (PRF) adhesive and a Forintek-developed resin modifier, eliminating the need to plane the treated lumber before gluing. This also eliminates the problem of planer shavings disposal. Field tests of the treated MPB glulam beams are being set up this year.

KEYWORDS: *glulam, MPB wood products, termite resistence, thermal treatment, value-added treatments.*

Contact Information

1 FPInnovations–Forintek, 2665 East Mall, Vancouver, BC V6T 1W5. Email: Martin.Feng@fpinnovations.ca

Feng, M. 2008. Value-added treatments for post-MPB wood products. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):175. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Abstract

Ethanol from hemicellulose extraction and fermentation

Steve Helle[1], Sheldon Duff[2], and Justin Matsui[3]

Presentation Abstract

Hemicellulose sugars form a significant portion of wood (i.e., 20–35% by weight). These sugars can be extracted from the wood, leaving the cellulose relatively intact. Once the hemicellulose sugars are extracted, they can be converted into by-products such as ethanol using a fermentation process. In this study, hemicellulose extraction from mountain pine beetle-killed wood was investigated. Dilute acid hydrolysis conditions (1% sulfuric acid at 130°C for 1 hour) resulted in sugar yields of 25%. Hydrolysis with no added acid was also successful in extracting hemicellulose sugars under harsher hydrolysis conditions (170°C for 4 hours). In both cases, the resulting sugar mixture was fermented to ethanol, with yields up to 75% of theoretical. The fermentation of the hemicellulose sugars extracted with water had higher yields than the sugars extracted with dilute acid.

KEYWORDS: *ethanol, hemicellulose, hydrolysis.*

Contact Information

1 University of Northern British Columbia, 3333 University Way, Prince George, BC V2N 4Z9.
Email: helle@unbc.ca

2 Chemical and Biological Engineering, University of British Columbia, 2360 East Mall, Vancouver, BC V6T 1Z3.
Email: duff@chml.ubc.ca

3 Chemical and Biological Engineering, University of British Columbia, 2360 East Mall, Vancouver, BC V6T 1Z3.

Helle, S., S. Duff, and J. Matsui. 2008. Ethanol from hemicellulose extraction and fermentation. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):176. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Wood decay and degradation in standing lodgepole pine killed by mountain pine beetle: Trees killed 1–10 years ago

Kathy Lewis[1] and R. Douglas Thompson[2]

Presentation Abstract

Despite the history of mountain pine beetle outbreaks in British Columbia, including the outbreak in the mid-1980s that affected timber supply in the Quesnel Timber Supply Area, little was known about the post-mortality rate of deterioration of factors of wood quality and quantity, and the rate of change in stand structure due to fall of dead trees. We used dendrochronology to cross-date pine killed by mountain pine beetle. We determined the exact year of mortality and characterized decay and degradation in factors of wood quality and quantity over time. Over 550 trees were sampled and successfully cross-dated, 122 of these had been dead for more than 6 years. At the stand level, 0.25% of the pine that had been dead for 5 years or less had fallen. In stands where trees were killed between 6 and 10 years ago, the average fall rate was 28%, ranging from 0 to 60%. We found that change in moisture content of the wood was the main driver behind the changes in checking (number and depth), saprot, and damage caused by wood borers. A small collection of biophysical variables explained the variation in the moisture content. These included tree size (DBH) and height of the tree. Biogeoclimatic unit and soil moisture regime were not important predictors of decay and degrade in this study, except for development of saprot at the base of the trees. Significant change in the above factors occurred within the first 1–2 years after mortality and varied with position along the stem and with the size of the tree.

KEYWORDS: *checking, decay, fall down, moisture content, saprot, shelf-life, wood products.*

Contact Information

1 University of Northern British Columbia, 3333 University Way, Prince George, BC V2N 4Z9.
Email: lewis@unbc.ca

2 University of Northern British Columbia, 3333 University Way, Prince George, BC V2N 4Z9.
Email: thompsor@unbc.ca

Lewis, K. and R.D. Thompson. 2008. Wood decay and degradation in standing lodgepole pine killed by mountain pine beetle: Trees killed 1–10 years ago. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):177.
URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Development of thick strand-based mountain pine beetle wood composites: Duration of load and permeability analyses

Azzeddine Oudjehane[1], Jasmine Wang[2], Chao Zhang[3], Greg D. Smith[4], and Frank Lam[5]

Presentation Abstract

A significant level of wood attacked by the mountain pine beetle (MPB) is entering the timber supply chain in northern/interior British Columbia. New products made from thick strand-based structural composites can help absorb this large volume of MPB-killed wood. A thick strand-based MPB wood composite product has been developed and prototype samples processed at the University of British Columbia. However, new wood products for structural applications must be tested to determine the response to long-term loading. Creep and duration-of-load behaviour are typical properties related to the product's structural performance under stress. To investigate the serviceability and structural safety of thick strand-based MPB wood composites, a systematic set of experiments was initiated to study the creep and duration-of-load behaviour of prototype samples. This experimental data will be used to calibrate a mathematical model and to develop a database of long-term properties of thick strand-based MPB wood composites. The effects of density and strand orientation on the in-plane permeability of thick, strand-based wood composites were also investigated. An apparatus was designed to seal samples inside and enable the in-plane permeability measurement. Twenty panels containing five density levels were made in the laboratory; three flow directions were measured. Empirical equations were also developed to predict the in-plane permeability of panels with a composition similar to the tested ones. A more complete understanding of mat permeability will optimize the press cycle time, throughput, and production costs of thick, strand-based MPB wood composites.

KEYWORDS: *creep, mountain pine beetle wood, permeability, strand composites.*

Contact Information

1 Wood Science, University of British Columbia, 2424 Main Mall, Vancouver, BC V6T 1Z4.
Email: oudjehane@forestry.ubc.ca

2 Wood Science, University of British Columbia, 2424 Main Mall, Vancouver, BC V6T 1Z4.
Email: jasmin_w@interchange.ubc.ca

3 Wood Science, University of British Columbia, 2424 Main Mall, Vancouver, BC V6T 1Z4.
Email: zhangch@interchange.ubc.ca

4 Wood Science, University of British Columbia, 2424 Main Mall, Vancouver, BC V6T 1Z4.
Email: gsmith@interchange.ubc.ca

5 Wood Science, University of British Columbia, 2424 Main Mall, Vancouver, BC V6T 1Z4.
Email: frank.lam@interchange.ubc.ca

Oudjehane, A., J. Wang, C. Zhang, G.D. Smith, and F. Lam. 2008. Development of thick strand-based mountain pine beetle wood composites: Duration of load and permeability analyses. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):178–180. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***

Introduction

To absorb the large volume of wood killed by the mountain pine beetle (MPB), a thick, strand-based wood composite product was developed and prototype samples processed at the University of British Columbia. Additional fundamental knowledge is needed to consider the effects of heat and mass transfer phenomena during pressing, and the structural behaviour of the product under long-term loading.

Creep and duration of load (DOL) are typical structural performance behaviours under long-term loading; permeability determines the heat and mass transfer during pressing of the end product. Therefore, as part of the development of these composite products, creep, DOL behaviour, and the in-plane permeability of prototypes were investigated in a series of experiments. The resulting data will be used to calibrate a mathematical model and to develop a database on the long-term properties of thick, strand-based MPB wood composites. The effects of density and strand orientation on the in-plane permeability were also investigated to obtain a better assessment of mat permeability in the composites and thus optimize the press cycle and production costs.

Methods

Before studying the creep and duration-of-load behaviour of the composites, 18 thick, strand-based MPB wood boards (76 × 76 cm) were manufactured in the laboratory; 350, 40 × 38 × 660-mm beams were made from these boards (Figure 1). The initial sample population was subdivided into separate groups that possessed near-identical distribution form and scale for bending properties in accordance with American Society of Testing and Materials (2005) standard D6815-02a. The modulus of elasticity (MOE) from preliminary third-point, edge-bending tests of the composite samples was used as the basis for matching the population samples in groups.

FIGURE 1. Thick MPB strand composite specimens.

Results

Using the third-point, edge-bending method under load control, ramp-loading tests were performed to establish the short-term strength distribution for the sample population. The loading rate was set at 317 kg/min (700 lb/min), which resulted in a mean time-to-failure of 80 seconds. The relationship between short-term strength (MOR) and the stiffness of the samples (MOE) validates the use of the MOE-matching technique to subdivide the sample population (Figure 2).

Although the permeability of strand-based composites (e.g., oriented strand board [OSB]) has been the emphasis of numerous research studies, most have focussed on the permeability perpendicular to the plane. To optimize the processing of thick MPB strand composites, a more fundamental knowledge is required of the heat and mass transfer during the hot pressing process.

In this study, aspen was used as a control material in the permeability measurements. The findings and trends were then extended to beetle-killed pine strand

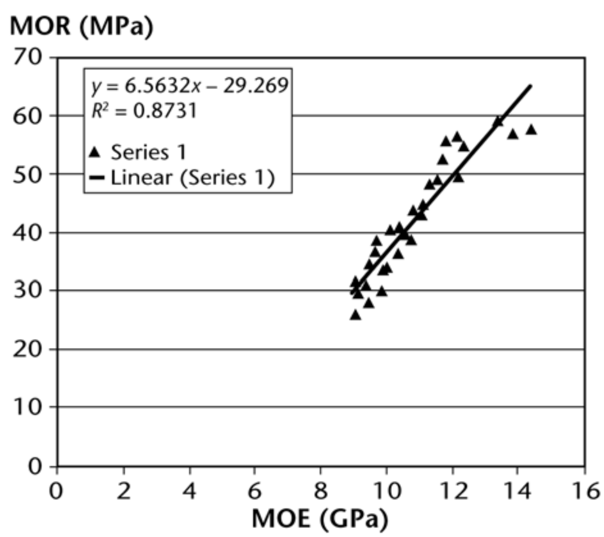

FIGURE 2. Relationship between MOR and MOE in thick MPB strand composites.

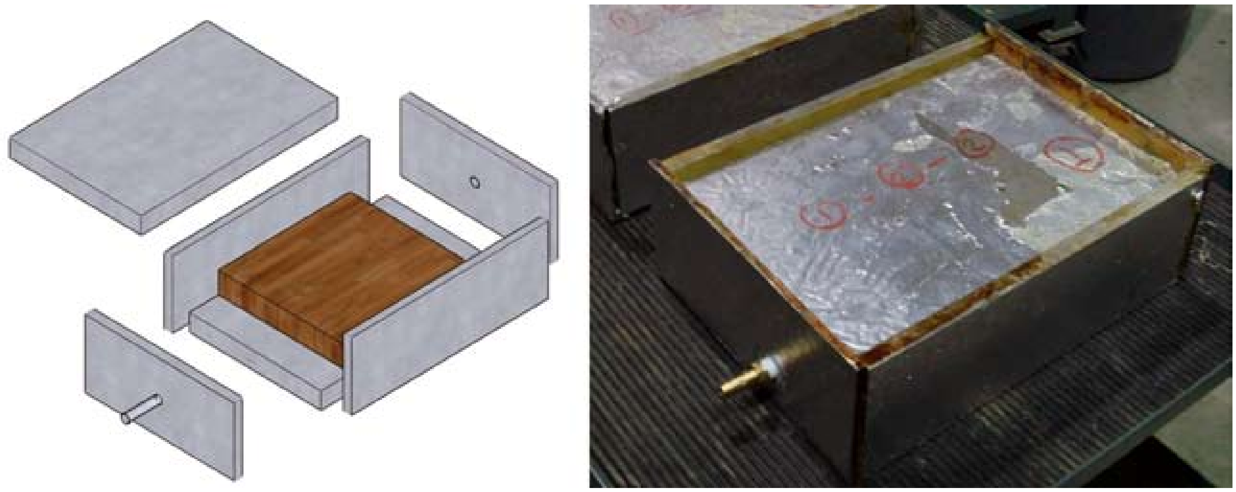

FIGURE 3. Permeability jig design and assembled for testing.

products. An aluminum jig (Figure 3) was constructed for in-plane permeability measurements. After the plates were glued together with hot-melt, they were connected to a permeability measurement apparatus, which was developed based on the theory of Siau (1971).

Four replicate thick strand boards using aspen strands were processed at five density levels (450, 550, 625, 700, and 800 kg/m^3). The sealing was applied before testing and trimmed afterwards so that one sample could be used to measure permeability in three principal directions.

Conclusions

Based on in-plane permeability measurements of aspen thick strand board products, the following conclusions were drawn:

- The in-plane jig designed for this project was capable of sealing samples well and provided reliable results in combination with the permeability apparatus.
- The permeability values for unidirectional thick OSB made from aspen decreased rapidly as the density increased. The decreasing trend diminishes as the density increases because all inter-strand voids are closed and air is forced to travel at a much slower rate through the strands themselves.
- Permeability is greatest in the parallel-to-strand direction, and lowest in the perpendicular-to-strand direction. Permeability in the 45° direction falls in between the two.
- Empirical equations were developed to predict in-plane permeability in different directions for several wood composites including thick MPB strand boards.

References

American Society for Testing and Materials. 2005. Standard specification for evaluation of duration of load and creep effects of wood and wood-based products. Standard D6815-02a.

Siau, J.F. 1971. Flow in wood. Syracuse University Press, Syracuse, N.Y.

Abstract

Mountain Pine Beetle/Natural Range Barrier Mitigation Program

Andrew W. Pantel[1] and Matthew Braun[2]

Presentation Abstract

The Range Branch of the B.C. Ministry of Forests and Range and the British Columbia Cattleman's Association are administering a Mountain Pine Beetle/Natural Range Barrier Mitigation Program. The purpose of the program is to mitigate the negative impacts of mountain pine beetle and mountain pine beetle salvage harvesting on livestock production by controlling livestock distribution and protecting environmental values on Crown range. Mitigation projects will replace natural range barriers and range developments lost or damaged during timber salvage harvesting and associated road construction (not associated with forest licensee responsibilities under the *Forest and Range Practices Act*). Range staff will use remaining resources to investigate and develop new opportunities for forage allocation. In addition, the projects address public and animal safety, provide a forage supply for existing clients, protect natural resources, and (or) prevent trespass of livestock.

KEYWORDS: *forage, livestock, natural range barrier, range.*

Contact Information

1 B.C. Ministry of Forests and Range, Range Branch, 1011 4th Avenue, Prince George, BC V2L 3H9.
Email: Andrew.Pantel@gov.bc.ca

2 B.C. Ministry of Forests and Range, Range Branch, 1011 4th Avenue, Prince George, BC V2L 3H9.
Email: Matthew.Braun@gov.bc.ca

Pantel, A.W. and M. Braun. 2008. Mountain Pine Beetle/Natural Range Barrier Mitigation Program. *In* Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. *BC Journal of Ecosystems and Management* 9(3):181. URL: ***http://www.forrex.org/publications/jem/ISS49/vol9_no3_MPBconference.pdf***