Forests for Tomorrow Adaptive Management Initiative

Synthesis of Information on Selected Topics & Clarification of Key Uncertainties

EXCERPT:

Risk of Fire after Mountain Pine Beetle

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The Forests for Tomorrow (FFT) program was established by the BC Government in 2005 in response to the devastating impact of major fires and the mountain pine beetle (MPB) epidemic on the forest land base of the Province. The program is aimed at improving the future timber supply and protecting other forest values through the re-establishment of young forests on lands that would otherwise remain underproductive.

The mountain pine beetle epidemic had affected over 10 million hectares of forest land by 2008 and is expected to expand further. This loss in forest cover is unprecedented in both scale and complexity. Many forest types have been affected across a range of ecological conditions from the dry Chilcotin to moist sub-boreal and high elevation zones. These twin factors of scale and complexity have, in turn, created numerous uncertainties for forest managers. Adaptive management strategies have been proposed as one approach for dealing with these uncertainties.

An adaptive management workshop held on June 26, 2008 under the FFT program for key staff engaged in restoring forest cover to the mountain pine beetle area raised a range of uncertainties or questions from participants. This is one of the topics for which our team was asked to review and summarize information in the existing literature.

Executive Summary

As a result of pine mortality from beetle attacks, concern has been expressed that uncontrollable wildfires similar to those experienced in Yellowstone National Park in 1988 would soon follow. As well, Forests for Tomorrow has expressed concern about the loss of seedlings planted beneath dead stands as a result of wildfire when compared to stock planted in clearcuts. While there is no question that the quantity and spatial distribution of fuels is changed in stands with a high proportion of mortality caused by mountain pine beetle, there is a lack of understanding about how these changes affect the risk of fire and the predictability of fire extent.

Several recent studies have shown that time-since-beetle outbreak is critical in understanding the relationship between beetle outbreaks, stand structure, fuel dynamics and fire risk. Nonetheless, empirical studies remain relatively few. The modeling and empirical studies reviewed here with respect to the question of how the quantity and spatial distribution of fuel change due to beetle attack affects fire behaviour and the predictability of fire extent, intensity and behaviour, suggest that:

- The majority of the studies undertaken in the spruce-fir forests did not support the hypothesized increase in fire occurrence, extent, or severity following insect outbreaks,
- Some results for the lodgepole pine-dominated forests indicate there is an increase in *surface* fire intensity in 0-5 years post-outbreak stands (caused by a pulse of surface fine fuels from dead trees) and in 5-60 years post-outbreak stands (caused by an increase in wind speed in the more open stands)
- BC fire experts expect that dead 20 to 30 year old stands will support intense fires that crown because of ladder fuels and abundance of ground fuels.

The degree to which dead boles increase fire hazard or severity is theoretical but not empirically known. The risk of underplanted seedling being killed in fires compared to the risk of seedlings in clearcuts is also unknown. But seedlings in clearcuts are frequently destroyed in major fires. Options to reduce fire hazard while maintaining attributes important for biodiversity over the landscape have not been well-explored.

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The Issue

As a result of mortality of pine from beetle attacks, concern has been expressed that uncontrollable wildfires similar to those experienced in Yellowstone National Park in 1988 would soon follow. As well, Forests for Tomorrow has expressed concern about the loss of seedlings planted beneath dead stands as a result of wildfire when compared to stock planted in clearcuts. While there is no question that the quantity and spatial distribution of fuels is changed in stands with a high proportion of mortality caused by mountain pine beetle, there is greater uncertainty as to how these changes affect the risk of fire and the predictability of fire extent compared to non-beetle attacked stands.

Theoretical Basis

We have a basic understanding of how fire that follows beetle attacks can affect ecosystems based on historical experience. Insect outbreaks that are followed by fire have been shown to disrupt or redirect succession in forest systems. For example, interactions of mountain pine beetle, lodgepole pine, and fire largely determine composition of subsequent stands. Outbreaks of mountain pine beetle in dead or dying lodgepole pine stands result in large fuel buildups (Stuart et al. 1989). If outbreaks are followed by intense wildfire that opens serotinous lodgepole pine cones, eliminates overstory vegetation, and exposes mineral soil then the sites return to a vigorous young stand of lodgepole pine (Amman and Schmitz 1988). However, when no fire occurs after an outbreak, lodgepole may be replaced by ponderosa pine at low elevation sites or by Douglas-fir at high elevation sites (Ahlgren 1974, Mitchell 1990).

Most literature from BC (Shore et al. 2006) promotes the theory that risk of fire after beetle attacks depends on time since attack. During first 2 to 3 years while most dead needles are retained on the tree there is a greater likelihood of a crown fire. Foliar moisture may be as low as 7% compared to live needle moisture content of just over 100%. Moisture in fine branchwood may be 20%, which is much lower than in live branches. Both changes lead to increased chance of combustion and more complete combustion during crown fires.

After needles drop to the forest floor, usually 2 to 3 years after death, risk of crown fires actually drop below those of live stands. Branches left in canopy will have lower moisture content but will not support crown fire because needles play a large role in crown combustion. Increased distances between crowns should reduce the likelihood of spread of crown fires. Fallen dead trees will increase surface fuel loadings increasing intensity and flame length and may cause standing residual dead and live trees to burn.

Loss of needles also means that more solar radiation and wind reach forest floor. The forest litter layer dries out more than under live canopy. More and drier fuel on the ground means higher intensity ground fires. About 10-15 years after the trees die, the large branches begin to fall and the tree stems break off creating a large accumulation of fuels that could support a more intense ground fire but still may not support crown fires.

Manning et al. (1982) described three primary periods of increased fire hazard in lodgepole pine stands following mountain pine beetle outbreaks. These periods again, are based on the changes in fuel quality noted in the paragraph above and theoretical understanding of ecosystem dynamics.

1. Immediately following an outbreak, when needles and small branches are retained on standing dead trees, stand susceptibility to crown fires may be increased. Understory response to the outbreak will also affect stand

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susceptibility during this period by altering the potential for simultaneous ground fire.

2. 10 years after an outbreak - an elevated fire hazard also occurs when tree bark begins to slough off.
3. 20 to 50 years after the outbreak - the most extreme hazard occurs after beetle-killed trees have fallen, approximately, and fuel-loading is at its maximum. Fuel quantity and arrangement may produce extremely high intensity fires.

Within the CFS (Taylor pers. comm., Hawkes pers. comm.) there is the belief that red needle stage is certainly at higher risk of ignition and the low foliar moisture will cause more spotting and crowning. Although they do not expect higher risk of ignition in grey attack stands they expect these stands to support higher fire intensities and higher rates of spread. Blackwell (pers. comm.) echoes these theoretically-based progressions.

Modeling and Empirical Studies

The BC literature notes that empirical evidence is very limited and Shore et al. (2006) reported only one empirical study, that of Turner et al. (1999) study in Yellowstone. Other empirical studies have been done by CFS, Pacific Forestry Centre. Hawkes (2008) noted that only a small number of escaped fires occurred in mountain pine beetle outbreak areas and fire sizes are confounded by fire suppression. Also, year to year variation in ignition events and weather confound separating effects of beetle on fire hazard and risk. In the few empirical measurements, the mean annual burn rate following mountain pine beetle outbreak is less than 0.02%. Hawkes also recorded fuel and overstory changes from some mountain pine beetle attacked areas (Table 2).

Table 2. Fine and coarse woody fuel loading and percent of overstory trees that have fallen over by study area (Hawkes et al. 2004 plus additions).

Location	Years Since MPB attack	<=7cm fine wood fuel load	>7cm coarse wood fuel load (t/ha)	%overstory trees that have fallen
Current outbreak				
Manning Provincial Park	0	4.3(t/ha)	45(t/ha)	No fall down
Tetachuck Lake	4	5.6(t/ha)	24(t/ha)	No fall down
Past MB Outbreaks				
Kootenay National Park	10	3.5(t/ha)	44(t/ha)	24
Chilcotin Plateau	16	5.3(t/ha)	28(t/ha)	52
Waterton Lakes National Park	19	6.8(t/ha)	42(t/ha)	52
Flathead study (Coates 2008)	20	Not reported	Not reported	100
F P B Chilcotin study (FPB 2007)	25	Not reported	32 to 166 m3/ha	0 to 80 depending on plot. Average 45
Chilcotin (Waterhouse and Armleder 2004)	15 to 20	?	?	70
Vanderhoof SBS (Lewis 2007)	5			5
Py study in Kamloops (Vyse pers. comm.),	4	Not reported	Not reported	25 for larger stems
Oregon thinned (Mitchell and Preisler 1998)	8 12			50 90
Oregon unthinned Mitchell and Preisler 1998)	9 14			50 90
Oregon Py (Keen 1955)	5 25			15 90

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An important conclusion from BC studies is that differing disturbance histories and ecological conditions cause substantial variation in fine and coarse surface woody fuels both before and after beetle attacks, making generalizations difficult.

Researchers from the University of Wisconsin (Simard et al. 2008) have recently summarized the literature pertaining to fire-bark beetle interactions. Their summary incorporates some literature from BC and agrees with the small amount of other empirical literature from BC. We repeat their summary, largely verbatim, below.

Simard et al. (2008) note that the potential effect of bark beetle outbreaks on fire hazard has been discussed for a long time (reviewed by McCullough et al. 1998, Parker et al. 2006, Lynch 2006), but only recently have studies presented empirical data to detect and quantify this relationship. Some authors have claimed that beetle outbreaks set the stage for catastrophic wildfires (Hopkins 1909, Brown 1975, Geiszler et al. 1980, Parker and Stipe 1993), whereas others have stressed the importance of time since beetle outbreak (Gara et al. 1985, Schmid and Amman 1992, Romme et al. 2006) and have theorized that crown fire risk might be increased only during the first year or two after an infestation because of dead needles still on the trees. After the dead needles fall to the ground, the risk of crown fire might actually be lower than pre-outbreak conditions because of reduced canopy continuity and bulk density, two important predictors of crown fire rate of spread. One to several decades after the outbreak, when beetle-killed snags fall on the ground and understory tree growth creates ladder fuels, the risk of crown fire may again be increased (Gara et al. 1985, Romme et al. 2006).

Recently published empirical studies have used two approaches to quantify the effect of bark beetle outbreaks on fire risk. Some studies have used a retrospective approach, comparing observed with expected patterns of area burned in a landscape that was previously affected by bark beetle outbreaks, whereas others have looked at potential fire behavior based on behaviour models and populated by fuel loadings sampled in the field (Table 2). Retrospective studies were done in spruce-fir (*Picea engelmannii-Abies lasiocarpa*) forests in Colorado (Bebi et al. 2003, Kulakowski et al. 2003, Bigler et al. 2005, Kulakowski and Veblen 2007) and in lodgepole pine (*Pinus contorta* var. *latifolia*) forests in Wyoming (Turner et al. 1999; Lynch et al. 2006), and looked at the change in fire occurrence and/or severity.

The majority of the empirical studies undertaken in the spruce-fir forests did not support the hypothesized increase in fire occurrence, extent, or severity following spruce beetle or MPB outbreaks at any of the time-since-beetle intervals (range = 0-60 years) that were studied (Bebi et al., 2003, Kulakowski et al., 2003, Kulakowski and Veblen, 2007). One study (Bigler et al. 2005) found a slightly elevated probability of high severity burns 60 years after a SB outbreak. However stand structure was by far a better predictor of fire severity than occurrence of previous beetle outbreaks *per se*, suggesting that stand structure, not tree mortality, was the driver of fire severity (Bigler et al. 2005).

Results for the lodgepole pine-dominated forests are less clear. Turner et al. (1999) found that probability of severe fire increased with severe MPB damage and in late-successional stands, whereas it decreased with light or moderate beetle damage and in mid-successional stands; however since beetle damage occurs primarily in late successional stands, and because these two variables were analyzed independently, it is not possible to untangle their respective effects. Using historical data in Yellowstone National Park, Lynch et al. (2006) found that the 1988 fires were slightly more likely (+11%) to occur in areas that were damaged by the mountain pine beetle in the 1970s, but there was no change in fire risk associated with the outbreaks of

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the 1980s. Lynch considered presence or absence of fire and not fire severity, which might explain why successional stage was not a significant variable in her analyses, contrary to the findings of other researchers (Renkin and Despain 1992, Turner et al. 1999).

Studies that have looked at potential fire behavior (Page and Jenkins 2007a, 2007b; Jenkins et al. 2008) have compared undamaged stands to stands that were damaged recently (0-5 years post outbreak) or decades ago (5-60 years post-outbreak, the range is broad but is as specific as reported in Simard et al. 2008's paper, and see Table 3 below) in three beetle/forest systems: DFB/Douglas-fir, MPB/lodgepole pine, and SB/Engelmann spruce (Table 3). These studies have found a consistent increase in *surface* fire intensity (fireline intensity and rate of surface fire spread) in 0-5 years post-outbreak stands (caused by a pulse of surface fine fuels from dead trees) and in 5-60 years post-outbreak stands (caused by an increase in wind speed in the more open stands). Probability of *crowning* (that is, the probability that a surface fire ignites tree crowns) was not tested in 0-5 years post-outbreak stands but was predicted to increase in 5-60 years post-outbreak stands because of lower crown base heights (that is, more ladder fuels allowing fuel continuity between forest floor and forest canopy) and higher surface fire intensity. However, *rate of crown fire spread* was **reduced** in 5-60 years post-outbreak stands because the density of the canopy (which needs to be above a certain threshold to allow active crown fires) was reduced by the beetles, which thinned the forest. This predicted reduction (or at least lack of increase) in active crown fire risk in post-outbreak stands support retrospective studies (see above) that have shown no effect of bark beetle outbreaks on occurrence of stand-replacing fires.

Table 3. Published empirical studies on bark beetle effects on fire activity.

Reference	Type of study	State	Forest Types	Bark beetle species (*)	Time since beetle (yrs)	Effect of bark beetle outbreaks on:	
						Fire occurrence or extent	Fire severity or behavior
Kulakowski and Veblen 2007	Retrospective	CO	Spruce-fir	SB, MPB	5	No effect	No effect
Bebi et al. 2003	Retrospective	CO	Spruce-fir	SB	0-50	No effect	NA
Kulakowski et al. 2003	Retrospective	CO	Spruce-fir	SB	0-50	No Effect	NA
Bigler et al. 2005	Retrospective	CO	Spruce-fir	SB	60	NA	Minor increase in severity †
Lynch et al. 2006	Retrospective	WY	Lodgepole pine	MPB	7,17	7=No effect;15= minor increase	NA
Turner et al. 1999	Retrospective	WY	Lodgepole pine	MPB	7-15	NA	Increase in severity †
Page and Jenkins 2007a, 2007b	Fuel sampling + potential fire behavior modeling	UT, ID	Lodgepole pine	MPB	5,20	NA	5 = increased surface fire intensity and rate of spread; crowning and crown rate of spread not tested; 20 = increased surface fire intensity and rate of spread; increased risk of crowning; reduced crown rate of spread

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Reference	Type of study	State	Forest Types	Bark beetle species (*)	Time since beetle (yrs)	Effect of bark beetle outbreaks on:	
						Fire occurrence or extent	Fire severity or behavior
Jenkins et al. 2008	Fuel sampling + potential fire behavior modeling	UT, ID	Douglas-fir, Lodgepole pine, Spruce-fir	DFB, MPB, SB	0-5, 5-60	NA	0-5 = increased surface fire intensity and rate of spread; crowning and crown rate of spread not tested 5-60 = increased surface fire intensity and rate of spread; **

* DFB, Douglas-fir beetle; MPB, mountain pine beetle; SB: spruce beetle
** Data not shown in paper
† possible confounding of stand age and succession
N.A., not applicable

Conclusion

Studies have shown that time-since-beetle outbreak is critical in understanding the relationship between beetle outbreaks, stand structure, fuel dynamics and fire risk. The modeling and empirical studies reviewed here suggest that with respect to the question of how beetle attacks affect fire behaviour and the predictability of fire extent, intensity and behaviour, the following general conclusions are possible;

- In the spruce-fir forests the hypothesized increase in fire occurrence, extent, or severity did not take place,
- In lodgepole pine-dominated forests there is an increase in *surface* fire intensity in 0-5 years post-outbreak stands (caused by a pulse of surface fine fuels from dead trees) and in 5-60 years post-outbreak stands (caused by an increase in wind speed in the more open stands)
- 20- to 30-year-old stands killed by MPB will support intense crown fires because of ladder fuels and abundance of ground fuels.

Studies that will be Informative in the Future

Some studies are underway that will help assess fire risk in MPB killed stands. Initiated in 2005, the Carrott Lake Mountain Pine Beetle Experimental Fire Study is being 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 killed by mountain pine beetle. The experimental plots are relatively small and range in size up to 200x200m (4ha). 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. There is also some work being done by CFS in Alberta looking at ignition of fires in dead stands. CFS is also involved with researchers at University of Victoria to try and untangle the effects of weather, suppression, and post-beetle fire events (Taylor pers. comm.).

The Canadian Forest Service (Beukema and Robinson 2004) has modelled stand structure and fuel changes after mountain pine beetle using Prognosis and FFE (Fire and Fuels Extension) models. Their simulations showed that the models do not accurately reflect build up of large fuels (underestimated) or fine fuels (overestimated), and do not capture snag dynamics well. These models need further calibrating before they are useful for predicting fire risk or potential.

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Management Options

If risk of surface fires increases a few years after pine beetle attack and again 10 or 20 years after as trees fall, then some fuel management maybe appropriate to protect areas of high investments in planting. Hot fires in August will burn areas regardless if they have had fuel management, but in less severe fire situations fuel management can affect spread and intensity of fires. The location of activities to reduce fuels should be planned to consider focal areas of planting. Interspersing planted stands (in either underplanted or clearcut situations) in areas with dead pine will place those stands at greater risk of burning than if they were concentrated in areas where fuels have been controlled. Young stands can be effective fuel breaks, but not if they have considerable ground fuels and not if they are scattered throughout unmanaged stands. There needs to be a balance between risk of fire, the values being protected and the costs of protection treatments. Treatments to reduce fuels should be targeted to protect areas of considerable regeneration investment.

Key Uncertainties

The degree to which dead boles increase fire hazard or severity is theoretical but not empirically known. The risk of underplanted seedling being killed in fires compared to the risk of seedlings in clearcuts is also unknown. Options to reduce fire hazard while maintaining attributes important for biodiversity over the landscape have not been well-explored.

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