Chapter 7

Preventive Management

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Abstract

Except for wildfire suppression, management and utilization of lodgepole pine, *Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm., was essentially ignored in western Canada until quite recently. Consequently, the landscape now includes many older stands that matured without any silviculture to modify characteristics that make them susceptible to mountain pine beetle (*Dendroctonus ponderosae* Hopk. [Coleoptera: Scolytidae]) outbreaks. Susceptibility of this forest to extensive mountain pine beetle damage is an outcome of well-understood ecological relationships between the insect and its host acting on the current condition and distribution of the lodgepole pine forest. Whatever the management objective for a landscape unit, the key to reducing future damage is the same: consistent application of well-planned management to prevent infestations at the stand level and to relieve forest-level conditions that allow rapid expansion of local infestations to landscape-level outbreaks. This chapter describes the basic principles of preventive management based on key interactions between lodgepole pine and mountain pine beetle.

Résumé

Jusqu'à tout récemment, pratiquement aucune attention n'était portée à l'aménagement et à l'utilisation du pin de tordu latifolié, *Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm., dans l'Ouest du Canada, sauf pour l'extinction des feux de forêt. Par conséquent, le paysage de cette région comprend maintenant de nombreux peuplements plus âgés qui ont vieilli sans qu'aucun traitement sylvicole n'y soit pratiqué pour modifier les caractéristiques qui les rendent sensibles à des infestations du dendroctone du pin ponderosa (*Dendroctonus ponderosae* Hopk. [Coleoptera: Scolytidae]). La vulnérabilité de cette forêt à des dégâts à grande échelle causés par le dendroctone est l'aboutissement d'une interaction écologique bien connue entre l'insecte et son hôte qui agit sur l'état actuel et la répartition de la forêt de pins de tordu latifolié. Quel que soit l'objectif d'aménagement d'une unité de paysage, la clé du succès pour réduire les dégâts futurs reste la même : l'application systématique de mesures d'aménagement bien planifiées visant à prévenir les infestations au niveau du peuplement et à remédier aux conditions forestières qui favoriseraient une propagation rapide des infestations locales et même une flambée à l'échelle du paysage. Le présent chapitre décrit les principes de base d'un aménagement préventif qui sont fondés sur les interactions entre le pin de tordu latifolié et le dendroctone du pin ponderosa.

Introduction

Recent epidemic outbreaks of mountain pine beetle (*Dendroctonus ponderosae* Hopk. [Coleoptera: Scolytidae]) in western Canada are a result of well-understood ecological relationships between pine trees and the insect acting on the current forest conditions. Age, composition, and structure of lodgepole pine (*Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm.) stands and their distribution on the landscape are the key elements of forest condition and they may be changed with management over time. A good understanding of the insect – host relationship and of lodgepole pine stand dynamics enables forest managers to direct these changes to reduce the probability and severity of future outbreaks.

Lodgepole pine

Lodgepole pine is an aggressive pioneer species that thrives in a wide variety of habitats and that establishes readily on burned-over areas (Smithers 1961; Brown 1975; Lotan and Critchfield 1990; Koch 1996). Extensive pure and mixed lodgepole pine-dominated stands have occupied continental plateaus and mid-elevation habitats in mountainous regions of western Canada since soon after the last ice age (Schmidt 1989; Koch 1996). For thousands of years prior to European settlement, the age, composition, and structure of these forests was quite diverse in space and time because of frequent stand-replacing wildfires (Brown 1975). In striking contrast, many large fires during the early years of settlement, followed by increasingly intensive fire suppression without substitution of another stand-replacing disturbance, produced the very extensive tracts of older homogeneous lodgepole pine present today (Brown 1975; Lotan et al. 1985; Gara et al. 1985; Wong et al. 2003). In British Columbia, the area of lodgepole pine greater than 80 years of age increased from about 2.5 million ha in 1910 to more than 8 million ha in 1990 (Taylor and Carroll 2004). Lodgepole pine now contributes more volume to annual timber harvests in western Canada than any other softwood species, but extensive industrial harvesting of lodgepole pine is a relatively recent phenomenon (Smithers 1961; Kennedy 1985; Koch 1996).

Although aboriginal peoples used lodgepole pine for tipi, travois, and corral poles and burned some older forest to enhance forage, impacts of these activities were small at the forest level (van Hooser and Keegan 1985). Early European settlers also harvested lodgepole pine locally for building materials, mine timbers, railway ties, or fencing, and sometimes deliberately or accidentally set fires that burned large areas, which later regenerated to lodgepole pine. Wildfire suppression to protect communities and resource values intensified with development through the 20th century, but until about 1970, the developing timber industry in western Canada ignored vast expanses of lodgepole pine forest. Domestic and export markets favoured other readily available timber species. As a consequence, most lodgepole pine forest in Alberta and British Columbia is now found in extensive tracts of homogeneous stands of 80 to140 years of age. Most have developed without any silviculture to control species composition, form, patch-size, density or growth rate. As these stands naturally developed characteristics of interest to the timber industry (large piece size in moderately dense stands), they also became increasingly susceptible to outbreaks of mountain pine beetle (Safranyik et al. 1974,1975). Since then, competition between mountain pine beetle and humans to harvest mature pine trees has been intense (Gibson 1989).

Natural history of mountain pine beetle

Mountain pine beetle is native to western North America and, like fire, has long been a natural part of lodgepole pine ecosystems (Roe and Amman 1970; Wellner 1978; Stark 1978; Carter 1978; Kohler 1981). This insect causes little damage to forests at low population levels, but when populations build to an epidemic outbreak, timber losses occur at the landscape level and are normally severe. Where extensive tracts of susceptible lodgepole pine dominate, outbreaks may last 10 or more years and kill most large-diameter pine trees on hundreds of square kilometres. When that happens, management of all forest resources is disrupted and effects on forest-dependent values and communities persist for decades.

Large mountain pine beetle outbreaks have occurred periodically in western Canada throughout recorded history. Hewitt first noted significant outbreaks in British Columbia in 1910 (cited in Powell 1961) and since then reports of mountain pine beetle activity have been made more or less annually (Powell 1961; Graham and Miller 1989; van Sickle 1989; Ebata 2004). Historically, outbreaks have been restricted by climate to a portion of the pine forest (Safranyik et al. 1974; Amman et al. 1977). However, suitable range for mountain pine beetle has expanded during a recent warming trend and future outbreaks are now likely at higher elevations or more northerly latitudes than in the past (Carroll et al. 2004). Increasing mountain pine beetle activity is already becoming apparent beyond the northern limit of its historical range in British Columbia and on the eastern slopes of the Rocky Mountains in Alberta (Carroll et al. 2004). The potential for future expansion into jack pine, *P. banksiana* Lamb., forests across Canada has been discussed (Ono 2004). Lessons learned in areas historically subject to outbreaks may be applied in all of these forests.

History of research and management

Amman and Logan (1998) reviewed the evolution of mountain pine beetle control in western North America and its relationship with research and experience. As interest in the timber value of lodgepole pine grew, mountain pine beetle research progressed from an initial focus on taxonomy and distribution (Hopkins 1902; Swaine 1918) to ecology of insect-host interactions (e.g., Hopping and Beall 1948; Reid 1963) and methods to destroy beetles through direct control (e.g., Hopkins 1905; Hopping and Mathers 1945). With improved understanding of ecosystem dynamics and a broadening of forest management objectives, the emphasis increasingly shifted away from managing the pest to managing the forest to reduce damage (e.g., Roe and Amman 1970; Safranyik et al. 1974).

Silvicultural treatments specifically directed at mountain pine beetle began in 1938 with a crop-tree thinning experiment in ponderosa pine (Eaton 1941). In lodgepole pine, Hopping (1951) recognized that "...treating infested trees is only a palliative..." and suggested that a more permanent solution lay in increased utilization and type conversion. Initially, types of silvicultural treatments suggested and researched for lodgepole pine were targeted to existing mature stands based on observed relationships between outbreak hazard, stand age, stand composition, diameter distribution, and stand density (e.g., Hopping 1951). As utilization of lodgepole pine increased, these observations also gave rise to suggestions to create age and species mosaics (Amman and Safranyik 1985; Amman and Schmitz 1988) and to manage lodgepole pine on short rotation in high hazard areas (e.g., Smithers 1961).

Diameter-limit cuts (e.g., Cole and Cahill 1976; McGregor et al. 1987), thinning based on basal area reduction (e.g., Amman et al. 1977; Cahill 1978; Bennett and McGregor 1980), and selective removal of trees with thick phloem were tried in existing mature stands with mixed results (e.g., Roe and Amman 1970). Attention to the role of microclimate and tree spacing in addition to tree vigour in outbreak development increased. Shepherd (1966) discussed orientation and rates of beetle activity relative to heat and light intensity. Geiszler and Gara (1978) discussed the role of tree spacing in switching of attacks from a tree under attack to a nearby tree. Amman et al. (1988) suggested that change in microclimate was the principal factor responsible for reduced attack after thinning, and Bartos and Amman (1989) further discussed the role of stand microclimate in mountain pine beetle infestation. Based on this research and experience, current strategies for reducing susceptibility of existing mature stands are focused on achieving optimum microclimate, vigour, and inter-tree distance by thinning from below to regular spacing (Safranyik et al. 2004). Whitehead et al. (2004) documented the success of this approach for preventing outbreaks at the stand-level under several levels of beetle pressure from surrounding stands.

Most basic principles needed to manage forests to reduce beetle-caused loss were known by the mid-1970s (Safranyik et al. 1974). Since then, research has increasingly focused on developing decision aids, such as hazard- and risk-rating systems (Amman et al. 1977; Amman and Anhold 1989; Shore et al. 1989; Shore and Safranyik 1992; Shore and Safranyik 2004). Attention has gradually shifted from reactive (direct control) to proactive (preventive) mountain pine beetle management. There has also been increasing recognition of the need to integrate mountain pine beetle management with management of timber and non-timber resources (e.g., Bollenbacher and Gibson 1986). In Canadian National Parks in the Rocky Mountains, prescribed fire programs to increase forest diversity for wildlife habitat and reduce fire hazard have been adapted to consider mountain pine beetle susceptibility. Over the past decade, considerable research effort has focused on development of landscape-level models (Riel et al. 2004) to predict patterns of mountain pine beetle outbreak development, compare potential outcomes of control strategies, and project impacts on forest management objectives (Fall et al. 2004).

The purpose of this chapter is to present general principles for preventive management that are applicable to any landscape with a high proportion of lodgepole pine forest. The key elements of preventive management are a focus on long-term planning and consistent management to alleviate conditions that lead to outbreaks at the landscape level (Safranyik et al. 1974). We present an overview of this concept, in two parts:

1) landscape planning to prevent expansion to epidemic outbreaks; and
2) stand management to prevent incipient infestations.

Landscape planning

In this section we briefly discuss options for developing landscapes with low susceptibility to landscape-level damage. Planning to reduce landscape susceptibility must be based on basic biology and epidemiology of the mountain pine beetle and its relationships with the stand dynamics of lodgepole pine (Roe and Amman 1970; Safranyik et al. 1975; Peterman 1978; Safranyik 2004) and its distribution on the landscape. Whether emphasis is on managing pine for wildlife habitat, recreation, commercial timber or domestic water supply, the principles behind management to reduce damage from mountain pine beetle are the same; only the methods of implementing the required changes differ.

Three conditions must be satisfied for a landscape level outbreak to occur. First, several years of suitable weather (mild winters and warm, dry summers) are required to allow endemic populations to surpass a threshold where large trees can be successfully attacked. At that point, small patch "incipient infestations" begin developing where lodgepole pine and mountain pine beetle occur together. Second, at least some of these infestations must develop, unchecked by weather or management action, until they begin to export very high numbers of mountain pine beetles. Lastly, there must be an abundance of susceptible stands on the landscape to sustain high beetle populations. Periods of favourable weather occur from time to time throughout the range of mountain pine beetle, and the weather is not subject to management intervention. Timely and aggressive suppression of incipient infestations can slow or prevent transition to an outbreak at the landscape level, but in the current landscape of western Canada, direct control will remain difficult and costly until the underlying problem (a concentrated abundance of susceptible stands) is addressed and better access to remote stands is developed.

When planning preventive management, forested landscapes must be considered as a collection of stands where specific characteristics of individual stands and arrangement of stands relative to each other in space and time are both important in determining susceptibility. If climate is not limiting (Safranyik 1978), specific stand characteristics usually associated with outbreaks in natural stands include: stand age (more than 80 years at breast height); average tree diameter (greater than 20 cm); and stand density (750 to 1500 trees/ha) (Hopping and Beall 1948; Safranyik et al. 1974; Cole and Cahill 1976; Shore and Safranyik 1992; Shore et al. 2000). With age, trees become less resistant to the blue stain fungus carried by attacking beetles (Safranyik et al. 1975). Diameter is associated with food and space requirements needed to support brood development for expanding populations (Cole and Amman 1969; Amman 1972). Stand density affects tree vigour and within-stand microclimate, which in turn influence success of bark beetle dispersal, host selection, attack or brood development (Bartos and Amman 1989; Amman and Logan 1998). Growth modelling for pure lodgepole pine (Farnden 1996) suggests that unmanaged natural-origin stands, which start at any density between 900 and 9000 trees/ha at breast height age on land with typical site indices[1], will follow stand growth trajectories to a susceptible density and average diameter within 80 to 100 years (Fig. 1).

Susceptibility of any landscape unit to an epidemic outbreak depends on the amount of area in susceptible stands, how the stands are spatially arranged, and how easy they are to access for direct control of incipient infestations. The current landscape in western Canada is very susceptible. Examining age-class distribution of pine-leading stands in an area is a simple way of assessing the proportion of area carrying susceptible stands. Two-thirds of the lodgepole pine-leading forest of British Columbia is now in this age range (Fig. 2). It is the concentration of these contiguous susceptible stands across large areas that makes expansion of unchecked incipient infestations to landscape-level outbreaks highly likely through a combination of local population growth and long-range dispersal. This underscores the need to bring the current landscape under active management to prevent future epidemic outbreaks.

Planning long-term preventive management requires a ranking of pine stands based on relative susceptibility, while prioritization of short-term direct control options requires a ranking of stands for risk of significant loss over a shorter term (Shore and Safranyik 1992).

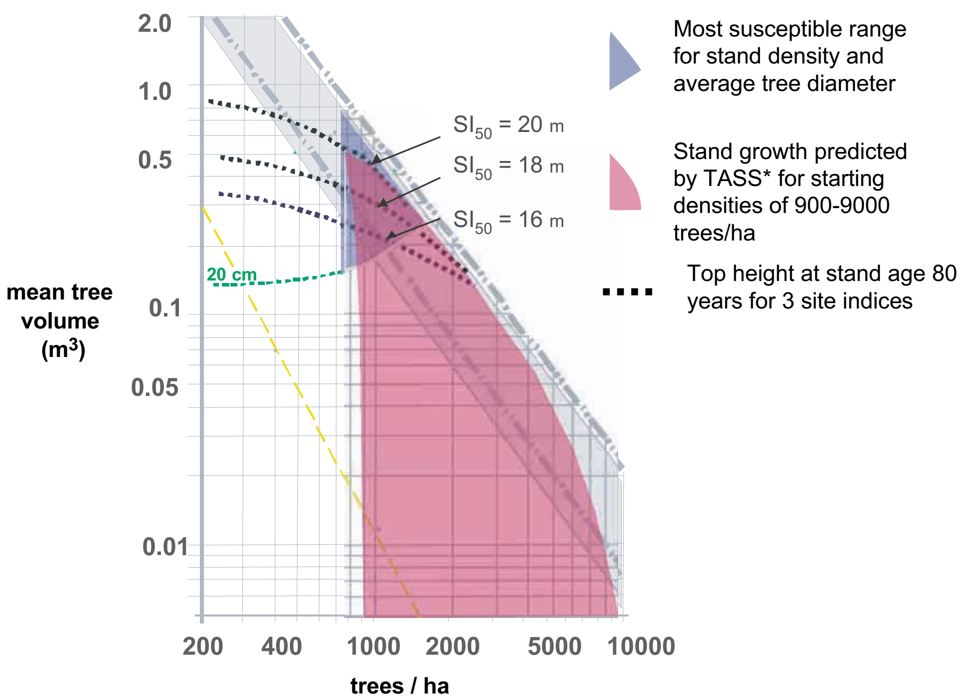

Figure 1. Stand Density Management Diagram for natural origin lodgepole pine, illustrating how all stands starting at breast height age from densities between 900 to 9000 trees/ha become susceptible to mountain pine beetle outbreaks within 80 to 100 years.

[1] Site Index (SI_{50}) is a measure of site productivity for a tree species, expressed as top height in metres at 50 years breast height age.

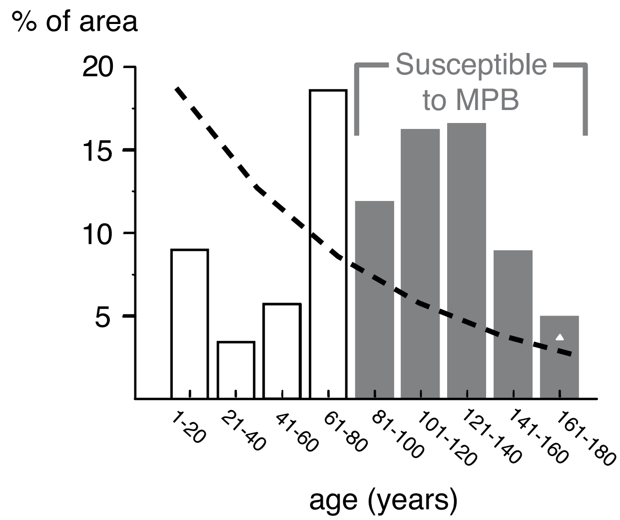

Figure 2. Age-class distribution of pine-leading stands in the SBS, SBPS, and MS biogeoclimatic zones of British Columbia. Dashed line indicates expected frequency distribution with a 100-year fire-return interval. (MPB = mountain pine beetle)

Hence, both detailed stand inventory information and consistent monitoring of bark beetle activity is required for rating stand susceptibility and risk. Over the past decade, introduction of Geographic Information Systems to forest operations, and increases in computing power, have made it possible to process data and plan efficiently for both short-term direct control and long-term stand replacement. Development of road access to mature pine stands for timely direct control of infestations, harvest of stands at highest risk, and proactive management of stand susceptibility are key elements in the planning process.

Stand replacement

The primary action required to lower current landscape susceptibility is reduction of the amount and concentration of susceptible lodgepole pine through planned stand replacement (Cole 1978; Cole and Amman 1980; Coulson and Stark 1982; Amman and Safranyik 1985; Cole and McGregor 1985; Amman and Schmitz 1988; Gibson 1989; Cole 1989). Logging and fire (whether prescribed or wild) are the main tools available. Targets for desired future age-class distribution and landscape pattern will depend on land use emphasis and landscape management objectives. As a general principle, a planner should strive to create a landscape mosaic with less old pine in smaller and more widely separated parcels, and a diversity of pine age classes and species mixes that will not favour the development of large-scale outbreaks (Amman and Safranyik 1985; Amman and Schmitz 1988).

Two of many possible low-susceptibility options for the lodgepole component of a landscape unit are illustrated in Figure 3. One scenario approximates average age-class distribution expected in unmanaged landscapes with a natural wildfire return interval of 100 years. Such might be a desired condition for lands managed as parkland or "wilderness." The other illustrates a sustained timber yield for commercial timberlands with most stands cycled on an 80-year rotation. Consistent management input is required to create and maintain either scenario over the long term.

If there were no mountain pine beetle, adjusting age-class distribution and redistributing it across the landscape in smaller patches would be relatively simple over time. Several decades of scheduled stand replacement based on a spatially explicit inventory (through timber harvest or prescribed burning), and subsequent stand management to adjust density, growth rate, or species composition, would create the desired landscape condition. In the presence of mountain pine beetle the process is more complex (Fig. 4). Access development and scheduling of stand replacement must be flexible enough to incorporate prompt direct control actions required to keep beetle populations low while adjustments to the forest mosaic are made.

Assessing risk and susceptibility of existing stands is a critical step in long-term planning for stand replacement. Consistent and thorough monitoring of the status and location of mountain pine beetle populations is necessary for risk rating and for directing control activities during incipient infestations. High-risk stands should be removed at the earliest opportunity. Access must be developed and maintained into areas of susceptible pine at lower current risk so that they can be broken into smaller patches in a mosaic with diverse age and species composition as opportunity allows. It is important to remember that the extensive mountain pine beetle damage seen over the last few decades developed because of the sheer size of the lodgepole forest and the high proportion of overmature stands where road access was poorly developed (making timely control difficult). Bringing forested lands under active management should relieve these conditions. Access development facilitates both monitoring and control of incipient infestations, while recycling stands on rotations shorter than 100 years limits potential damage by reducing the amount of susceptible pine at any one time.

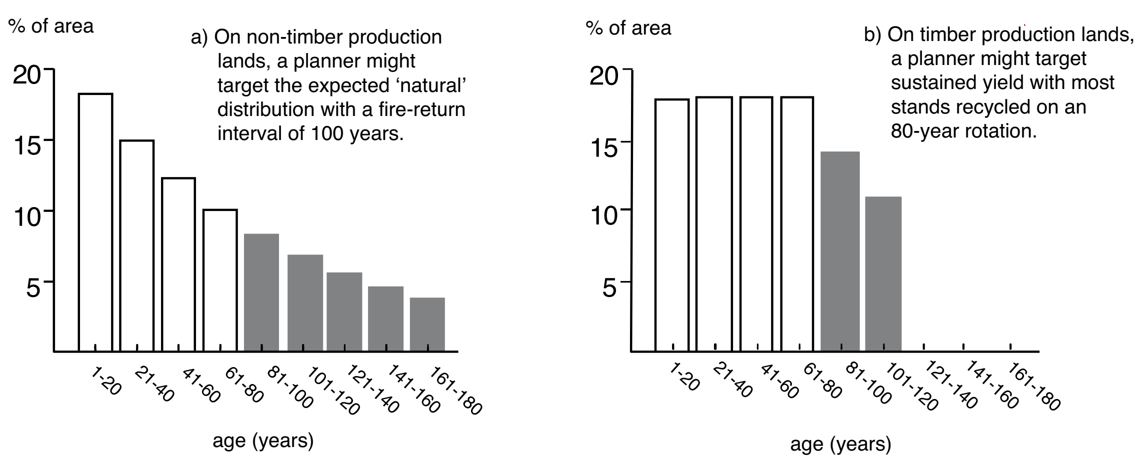

Figure 3. Two of many possible targets for the age-class distribution of pine stands in a landscape planning unit which would reduce the proportion of susceptible pine to less than 30% of the total.

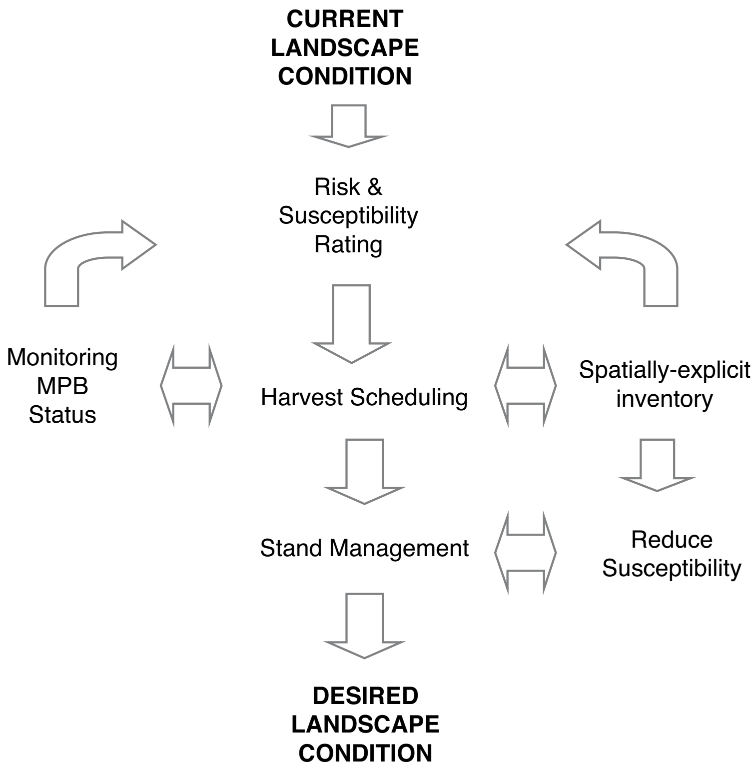

Figure 4. A simplified model for landscape management in pine-dominated operating areas. (MPB = mountain pine beetle)

Stand management

Here we briefly discuss stand-level management options for currently susceptible stands, and for planning and managing new stands to avoid the site and stand conditions that favour outbreaks. If applied as part of a landscape-level plan that reduces the amount and concentration of old lodgepole pine and promptly controls incipient infestations, stand-level management plays a key role in reducing damage.

Maintaining stand hygiene and vigour

Endemic mountain pine beetle populations generally require weakened or decadent trees for successful completion of their life cycle (Coulson 1979; Coulson and Stark 1982). Silvicultural practices which promote timber production, such as density management to limit inter-tree competition for moisture and nutrients, will produce more vigorous trees– ones less likely to succumb to attack when beetle populations are low. Similarly, silvicultural practices that promote stand hygiene can be effective in managing endemic mountain pine beetle populations to prevent their increase beyond endemic levels. Removing damaged or diseased trees during stand tending should limit endemic populations in stands managed for timber and reduce probability of incipient outbreaks when weather favours population growth (Cole 1989; Cole and McGregor 1985). Removal of larger-diameter trees infested with dwarf mistletoe, or damaged during stand tending, or weakened by wind or snow damage is especially important. During periods of weather favourable to beetle survival, such trees are very vulnerable and provide opportunities for expansion of mountain pine beetle populations to levels where even healthy trees may succumb to mass attack.

Managing species composition

Mountain pine beetle attack tends to hasten succession of lodgepole stands to climax forest types, and many existing lodgepole pine stands will succeed to more shade-tolerant species in the absence of a stand-replacing disturbance. In such cases, species conversion through selective removal of pine from mature mixed-species stands will contribute to the landscape plan to reduce the amount of susceptible forest while maintaining mature forest cover for other values. Discrimination against lodgepole pine in mixed stands during intermediate cuttings provides another way of varying the forest mosaic, and it may allow for longer rotations than is safe with pure stands (Cole 1989). Where appropriate and where needed in the landscape plan, species conversion can be achieved through preserving seed trees and advanced regeneration of nonpine species during stand replacement, or by planting alternative species after stand replacement.

Managing density in new pine stands

Stand characteristics that favour incipient outbreaks of mountain pine beetle are very like those associated with "physiological maturity," which is defined by the point in stand development at which current annual increment declines to below the mean annual increment (Safranyik et al. 1974). Onset of physiological maturity may be delayed by management actions that retain stand vigour, such as density management (Anhold and Long 1996). Density management is a very useful tool for preventive management because it can also be used to direct stand growth to meet specific product, timber supply, or habitat objectives (Farnden 1996).

Figure 5 illustrates how two silvicultural entries to a fully stocked, natural stand of lodgepole pine starting at 5000 trees/ha at breast height age on a site with SI_{50} = 18 m affect stand development. Without treatment ("1" in Fig. 5), the stand would self-thin to about 1500 trees/ha by 80 years of age, just reaching the average diameter where outbreaks typically develop. The stand could then be harvested, yielding 270 m^3/ha with an average piece size of 0.25 m^3. If beetle pressure was low, it could be left to grow with regular monitoring of mountain pine beetle activity. If the same stand is precommercially thinned to 1600 trees/ha ("2" in Fig. 5), it develops to about 1100 trees/ha at age 80 and could be harvested, yielding about 330 m^3/ ha with a larger average piece size, which may be more desirable if sawlogs are the product objective. If it is necessary or desirable to carry this stand to larger piece size or older age to meet some timber supply, habitat, or visual quality objective, a commercial thinning entry at about age 60 is an option. Removing approximately 100 m^3 of sawlog material would shift the growth trajectory away from conditions where outbreaks would ordinarily develop ("3" in Fig. 5), and potentially yield about 350 m^3/ha with large piece size at 100 years breast height age.

The above example illustrates only three possibilities. When stands are brought under active management, there are many possible pathways for stand development that will lead to acceptable end products with reduced stand and landscape susceptibility to mountain pine beetle.

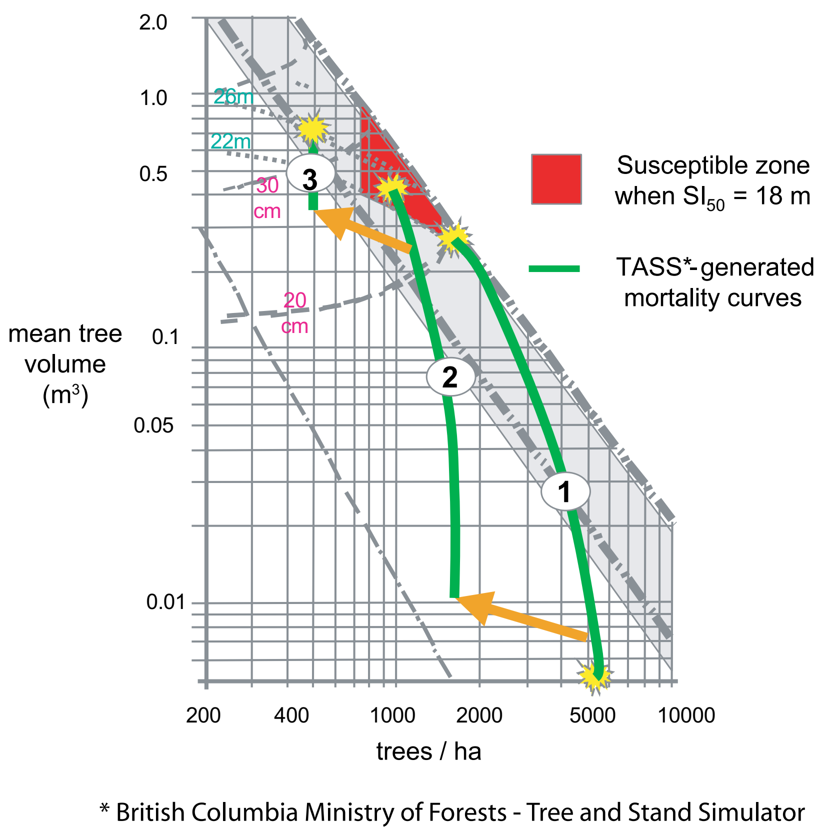

Figure 5. Stand Density Management Diagram for natural-origin lodgepole pine, with TASS-generated mortality curves illustrating how density management can lead to acceptable final products on an 80-year rotation or maintain low susceptibility to mountain pine beetle on an extended rotation (source: Farnden [1996]).

Managing density in existing mature natural stands

Removing susceptible diameter classes from pure pine stands by thinning from above (diameter-limit cutting or "high grading") may reduce susceptibility of mixed or pure stands for a limited time until residual trees grow to susceptible size and another removal is required. However, such a thinning regime generally leaves stands of reduced silvicultural value (Schmidt and Alexander 1985) with uneven stem distributions, and such stands are often vulnerable to wind or snow damage. Consequently, this option may have limited application.

In most of western Canada, it will be difficult to quickly replace all stands of high susceptibility without exceeding other constraints on harvest such as timber supply, visual quality, or habitat. Also, it is often important to hold some mature stands in the harvest queue while older stands or stands at higher risk are recycled. One tactic that has shown considerable promise is thinning some mature stands to a uniform inter-tree spacing at less than 600 trees/ha (also known as "beetle proofing"). The prescription requires thinning from below to enhance individual tree vigour (increasing the trees' ability to produce resins that are the primary defense against attack), and uniform spacing to create stand microclimate conditions (higher temperatures, light intensity, and within-stand winds) that hinder beetle dispersal, attack behaviour and survival (Bartos and Amman 1989; Amman and Logan 1998). To optimize these effects, stands must be opened to at least a 4-m inter-tree spacing (to increase wind penetration, light and temperature), with the largest, healthiest trees retained (for vigour and windfirmness). Damage to leave trees must be minimized to avoid stress. It is important to remember that increasing inter-tree spacing (not thinning to a target density or basal area) achieves the microclimate objectives. This prescription, which takes mature stands down to between 400 and 625 trees/ha, usually removes enough volume of sufficient piece size to ensure a commercially viable operation[2] in timberlands, and leaves stands with higher value for wildlife habitat, recreation and water management.

The Canadian Forest Service has been studying this "beetle proofing" prescription for more than a decade. Whitehead et al. (2004) reported preliminary results of two studies of interest. In the first, three levels of treatment (not treated, spaced to 4 m and spaced to 5 m) were applied in uniform 90- to 110-year-old lodgepole stands at each of three sites in the East Kootenays between 1992 and 1993. Microclimate was monitored in each treatment unit, and trees within each unit were monitored to document tree vigour. Results over the first decade indicated the prescription achieved the desired tree vigour (Fig. 6) and microclimate effects (Fig. 7).

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[2] Anon. 1999. Case study in adaptive management: Beetle proofing lodgepole pine in southeastern British Columbia. BC Ministry of Forests Extension Note EN-039.

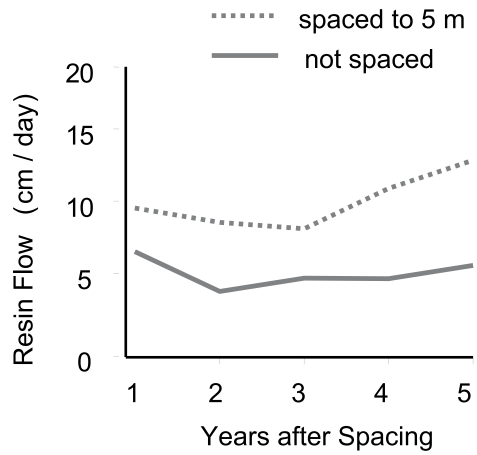

Figure 6. Comparison of resin production in response to wounding in spaced and unspaced stands from the East Kootenay Trial (mean of 10 trees/treatment on each of three sites). Source: L. Safranyik, D. Linton and A. Carroll, Canadian Forest Service, Victoria, unpublished data.

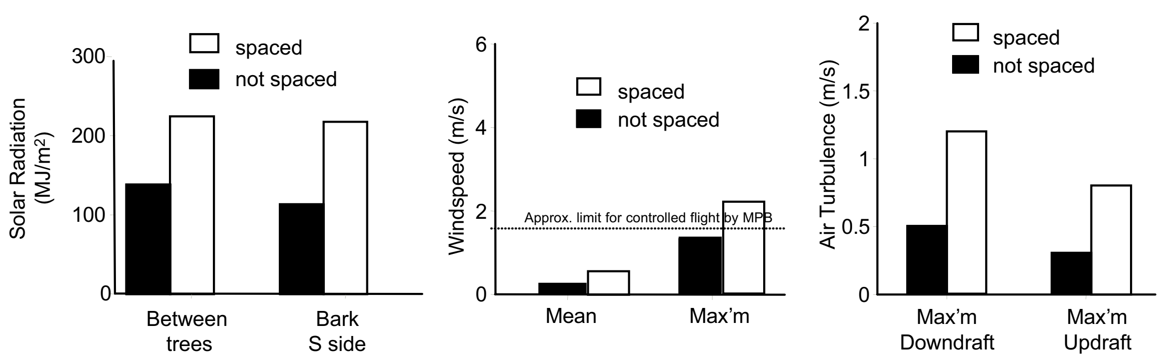

Figure 7. Comparison of three important within-stand microclimate parameters in spaced and unspaced stands from the East Kootenay Trial (5-year average on three sites for days in July and August when air temperature exceeds 18° C). Source: R.A. Benton and B.N. Brown, Canadian Forest Service, Victoria, British Columbia, unpublished data. (MPB = mountain pine beetle.)

The second study was conducted in 2003, when conditions favouring an increase in mountain pine beetle populations had persisted for at least 3 years (Whitehead and Russo 2005). It compared levels of beetle activity since treatment in five existing study areas where side-by-side demonstrations of beetle-proofed and untreated stands had been established between 1991 and 1994. Proportion and number of trees successfully attacked since treatment, and ratio of green attack to red attack over the last year, were both lower in beetle-proofed stands in every case. However, the magnitude of that difference reflected site-specific factors.

At three sites where aggressive direct control of incipient infestations in surrounding areas had kept rising beetle populations relatively low, untreated stands all developed incipient infestations that required direct control; beetle-proofed stands did not. At a fourth site, there was less mature pine in the surrounding area and no direct control program for the preceding two years. There, the proportion and density of trees attacked in the untreated stand was three to four times higher than in the thinned area, but green:red attack ratios were similar (1.8 and 1.4, respectively). In this case, the prescription had called for thinning to 500 trees/ha, rather than spacing to a minimum inter-tree distance and most attacks were found in patches of higher density left to compensate for natural stand openings or removal of damaged trees (i.e., where microclimate was still favourable for host selection and initiation of attack). It is important to remember that beetle proofing depends on final inter-tree spacing to achieve the desired microclimate and that thinning to a target stand density or basal area may not produce the tree distribution required.

The fifth site, located in a large expanse of untreated susceptible pine, was on the edge of a rapidly expanding uncontrolled outbreak and had been subjected to very high beetle pressure for the preceding 2 to 3 years. When the stand was assessed, about 35% of all trees in each unit had been attacked. In the untreated stand, this fraction included nearly three times the total number of attacks in the spaced stand (453/ha vs. 167/ha) and more than 80% of pine over 20 cm in diameter. Although green to red attack ratio was also lower in the spaced stand (1.2 vs. 3.3, respectively), the spaced stand is expected to succumb as the outbreak proceeds. Beetle proofing is intended to prevent transition between endemic and incipient phases of the outbreak cycle, and should not be expected to save stands during an epidemic.

The beetle proofing prescription is a useful tool, suited for limited application in areas where there is a reason to maintain mature forest cover in a specific place (such as maintenance of recreation value, riparian zone integrity, viewscape quality, or timber supply) while the amount and distribution of susceptible stands in the surrounding area are adjusted through stand replacement. Consistent monitoring and aggressive direct control of incipient outbreaks in surrounding areas are an important complement to this prescription.

Summary

The current landscape in western Canada includes an abundance of largely undeveloped older lodgepole pine stands that matured without active silviculture, and this landscape is very susceptible to development of landscape-level outbreaks of mountain pine beetle. Planned stand replacement is required to create a landscape mosaic with less old pine in smaller and more widely separated parcels, where age-class, size and species mixes will not favour development of large-scale outbreaks. Opportunities for reducing future susceptibility of replacement stands include conversion to nonpine species and management of pine on shorter rotations with density management to control stand growth, and attention to stand hygiene. There are also limited opportunities for stand-level management of current mature stands, including pine removal from mixed stands and beetle proofing some mature stands to provide flexibility for integrated management of multiple resource values on a landscape.

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