Mountain Pine Beetle Management and Decision Support

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Abstract

Management of mountain pine beetle involves strategies and tactics aimed at keeping beetle populations at endemic levels and maintaining vigorous stands. Tactics aimed at reducing beetle populations are termed "direct control" and those directed at maintaining stand vigour are called "preventative management". Decision support tools have been developed that provide valuable information so that managers can make informed choices on appropriate tactics and allocation of resources. Susceptibility and risk rating systems and spatial models are amongst the most useful of these decision support systems. A number of key questions that may be addressed through modelling or other research approaches are presented.

Introduction

There are three objectives that we address in this paper. The first is a review of some of the knowledge on the biology and epidemiology of the mountain pine beetle, which was presented by Carroll and Safranyik (2004), and placement of this knowledge in a management context. Our second objective is to provide an introduction to some of the decision support tools available for managing the mountain pine beetle. Some of these decision support tools are further discussed by Riel *et al.* (2004) and Fall *et al*. (2004). Our final objective is to provide a transition to the research component of this symposium by identifying some of the main knowledge gaps that are either being currently addressed or need to be addressed in the near future.

Population Dynamics

The mountain pine beetle is capable of causing devastating losses to mature pine forests, as we are currently witnessing in British Columbia (BC). This beetle is a native insect and is generally present in low numbers throughout its range. Periodically, one or both of two situations will result in the beetle population shifting from endemic to epidemic levels (Fig. 1).

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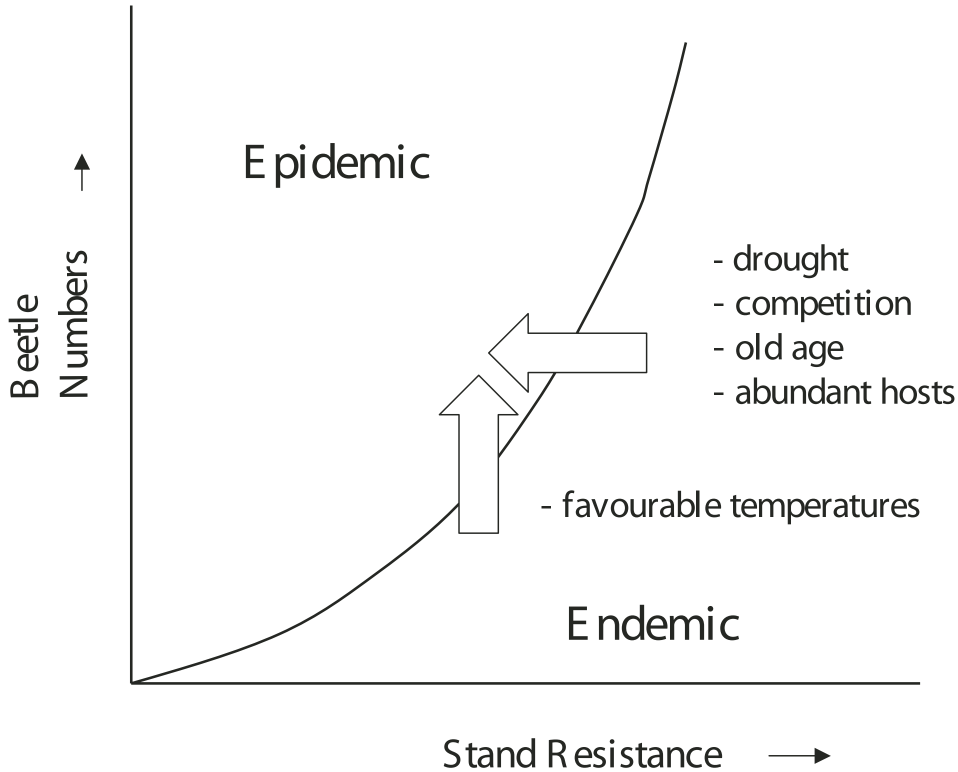

Figure 1. Factors contributing to mountain pine beetle shift from endemic to epidemic populations (after Berryman 1978).

Favourable weather conditions will increase the survival of the beetle during winter and the flight period and will result in a larger beetle population. This larger population is able to overcome the resistance of larger pine trees using their mass-attack behaviour, and thereby produces significantly higher numbers of progeny in these trees. Alternatively, or additionally, tree and stand susceptibility to attack by the beetle can be reduced during periods of drought, or if stands become too dense or old (Fig. 1). Depending on how widespread these optimum conditions are, the mountain pine beetle may be able to quickly increase in population. Once the population is large, there is a snowball effect where tree resistance is of little importance because large numbers of attacking beetles will eventually overcome the resin defenses of even the most vigorous trees. Given abundant host material, the mountain pine beetle will spread across the landscape, with dispersing beetles joining resident populations to achieve the critical mass required to successfully attack the larger trees in which they have the best survival and reproduction.

Management

We can utilize the knowledge that we have gained about the biology and epidemiology of the mountain pine beetle, and its interaction with its host, to aid in making decisions that will reduce losses to this insect. The nature of the decisions we have to make in resource management often depends on the population level of the mountain pine beetle.

To have a mountain pine beetle infestation, both a susceptible stand and a beetle population must be present. From a management point of view, our objective is to keep the beetle population low and to keep our stands vigorous. Treatments aimed at reducing beetle populations are termed “direct control” and those aimed at increasing stand vigour are termed “indirect control” or “preventative management” (Fig 2).

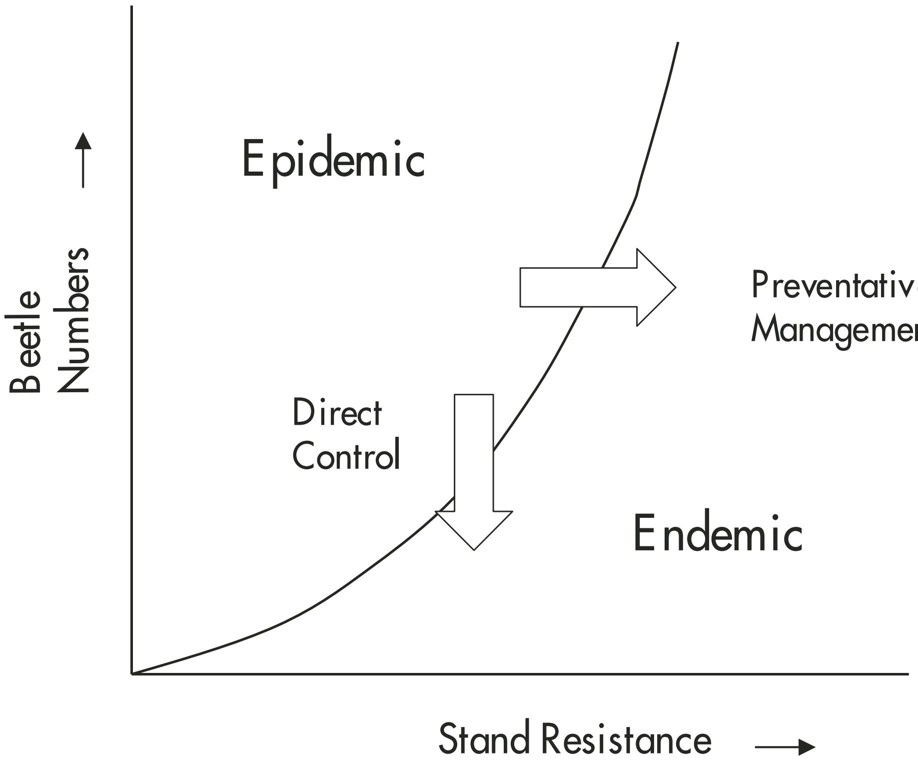

Figure 2. The role of population reduction (direct control) and preventative management in maintaining mountain pine beetle at endemic levels.

Direct control tactics are aimed at killing beetles under the bark of infested trees. The objective is to break the epidemic cycle by returning the population to the endemic phase (Figs. 2, 3). Direct control tactics include single-tree treatments such as removal and processing, felling and burning, de-barking or treatment with monosodium methanearsonate (MSMA). MSMA is a chemical solution squirted into an axe frill around the base of an infested tree within the first 3 or 4 weeks following attack while the tree is still alive. The chemical is drawn up through the conductive tissue of the tree and kills the beetles under the bark. Larger groups of infested trees are usually treated by block harvesting and processing. Pheromone baits may be applied to individual trees or stands to attract and concentrate beetles prior to treatment. Pheromones are naturally occurring attractants produced by members of a species to attract other members of the species. In the case of mountain pine beetle, pheromones are used to create the advantage of mass-attack to overcome the tree's resin defense system. Synthetic pheromones are commercially available and can be used to supplement management tactics.

Preventative management involves treatments aimed at reducing susceptibility at the tree, stand and landscape scales. This is done through increasing tree vigour, altering microclimate and reducing the amount of contiguous host. Thinning and spacing increases tree vigour as indicated by increased growth rates and resin production. It also alters the microclimate within a stand to one less favourable to mountain pine beetle in terms of wind speed, light and temperature (Whitehead et al. 2004). The contiguity of host can be altered through harvesting, fire, and silviculture by working towards the creation of a species-age mosaic on the landscape. This reduces the landscape-level susceptibility to the beetle and makes it more difficult for beetles to spread rapidly.

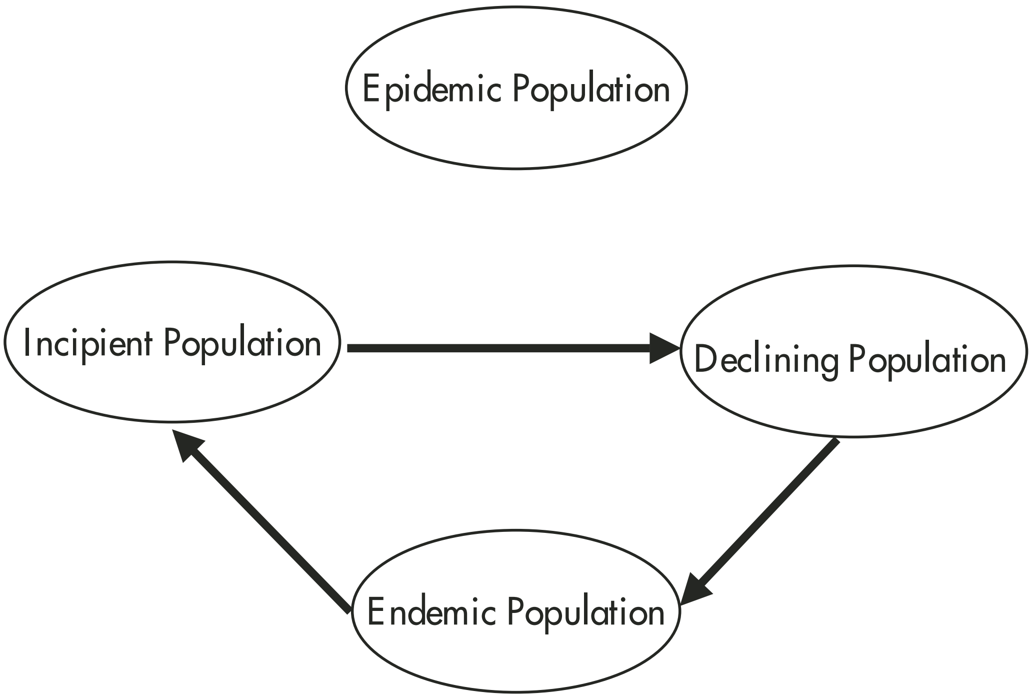

Figure 3. Breaking the cycle of mountain pine beetle epidemiology through direct control (population reduction).

Decision Support Tools for Mountain Pine Beetle Management

Susceptibility and Risk Rating Systems

During the endemic stage it is human nature to forget about the threat from mountain pine beetle and direct our efforts to other problems. This time, however, provides the prime opportunity for preventative management. The primary objective of preventative management is to reduce the susceptibility of trees, stands and landscapes. A stand susceptibility rating system can be used to locate stands with the highest potential for loss to the mountain pine beetle. The Shore and Safranyik (1992) stand susceptibility rating system is based on four main variables: stand age, stand density, stand location (latitude, longitude and elevation), and the percentage of stand basal area composed of larger pine. This decision support tool gives each stand a rating between 0 and 100 and allows resource managers to prioritize their stands for treatments. For preventative management the highest susceptibility stands should be given harvest priority. At a landscape level, susceptibility maps (Fig. 4) can be used to identify contiguous areas of high susceptibility that could be broken up through harvesting or fire.

The Stand Susceptibility Index relates to the eventual basal area killed in the event of a mountain pine beetle infestation (Shore et al. 2000) (Fig 5).

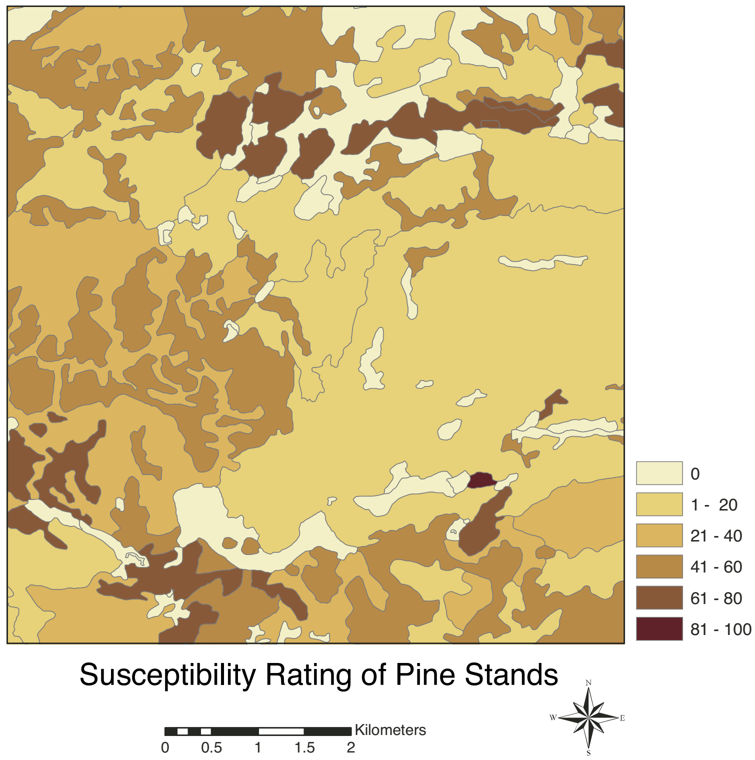

Figure 4. A stand susceptibility map based on Shore and Safranyik (1992) can be used to identify high susceptibility stands and contiguous areas of high susceptibility for setting priorities for treatment.

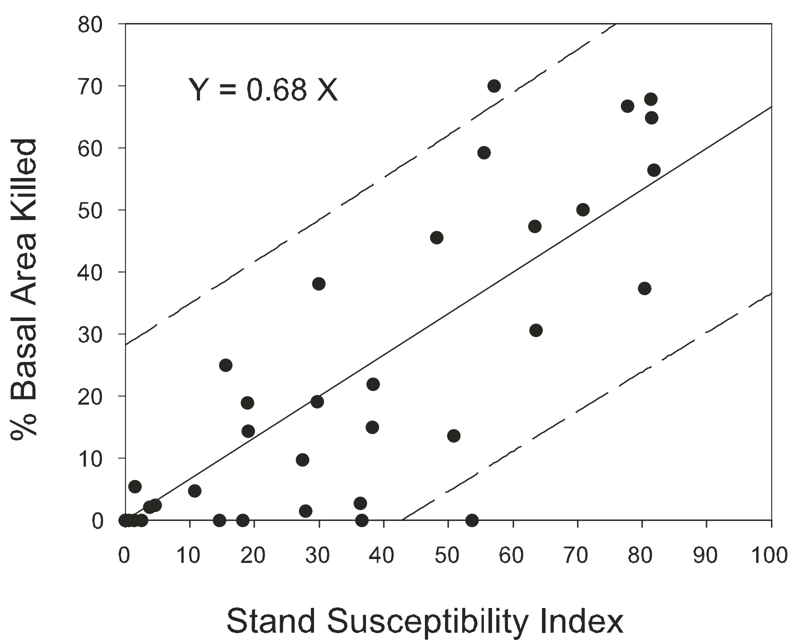

Figure 5. The relationship between the Shore and Safranyik (1992) Stand Susceptibility Index and the percentage of stand basal area killed following a mountain pine beetle infestation can be used for large scale (but not individual stand) predictions of loss (from Shore et al. 2000). Regression is $y = 0.68x$; $r^2 = 0.86$ (outside lines represent 95% prediction level).

The Stand Risk Index (Shore and Safranyik 1992) is an extension of the Stand Susceptibility Index that includes "beetle pressure". Whereas the Stand Susceptibility Index indicates the potential of a stand for damage in the event of an infestation, the Stand Risk Index incorporates the likelihood of that event occurring based on the proximity and magnitude of surrounding beetle populations. The risk index is used to set priorities for direct control during the incipient to epidemic stages of an outbreak.

The shift from the endemic to incipient phase of an outbreak can often be subtle and escape detection. The upper line in Figure 6 illustrates this point. A single infested tree in year 1 can result in 512 infested trees in year 10 if the population doubles each year. Although this shows the rapidity of an exponential increase in population, the infested trees in year 10 would still only represent about 2% of a 20-ha stand, and could be either missed in surveys or dismissed as insignificant. The lower line in Figure 6 illustrates another important point.

Treatment of three out of the eight infested trees in year 4 resulted in 194 fewer infested trees in year 10. The message here is that even partial treatment of infested trees can have some effect. Although this may only be a delaying tactic, it may provide additional time in which a negative weather event will affect the population, or at least it may provide time to mobilize against the epidemic.

During the incipient to epidemic phases, one of the crucial decisions to be made is the number of infested trees that need to be removed in an area to keep the infestation from growing. This information can be utilized to develop or alter strategies for managing mountain pine beetle infestations. If it is determined that the number of trees requiring treatment far exceeds the resources needed to carry out the activity then a decision is required on either increasing resources or shifting from a suppression to a maintenance or salvage strategy [see Hall 2004 for a discussion on beetle management strategies].

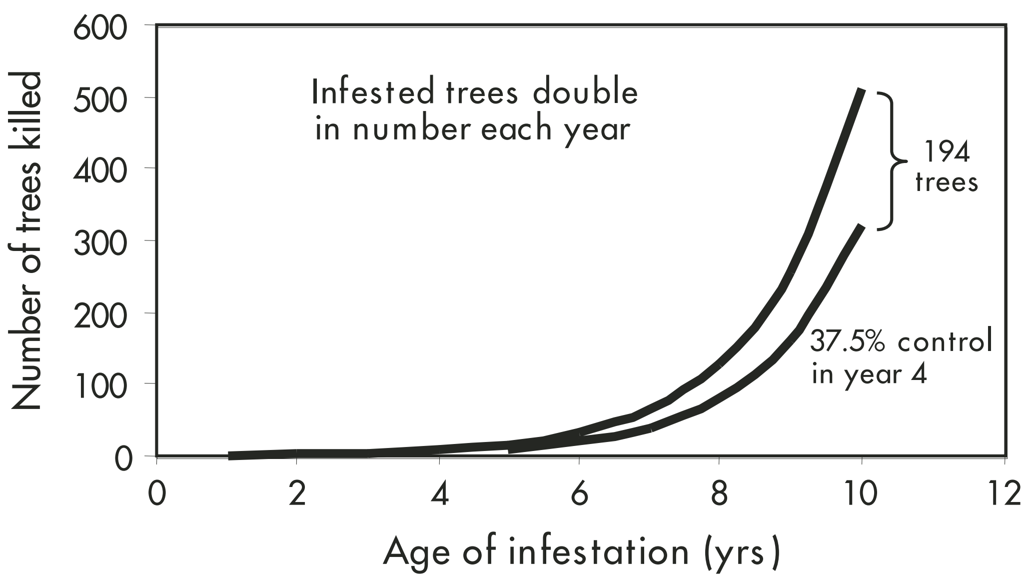

Figure 6. Growth in the number of infested trees over 10 years with and without partial treatment based on a single tree being infested in year one and a growth rate for infested trees equal to 2x. Treatment is three of eight infested trees being removed in year 4.

Rule of Thumb for Determining Number of Infested Trees Requiring Treatment

We have developed a decision aid that we refer to as a "rule of thumb" for determining the number of infested trees requiring treatment (Fig. 7).

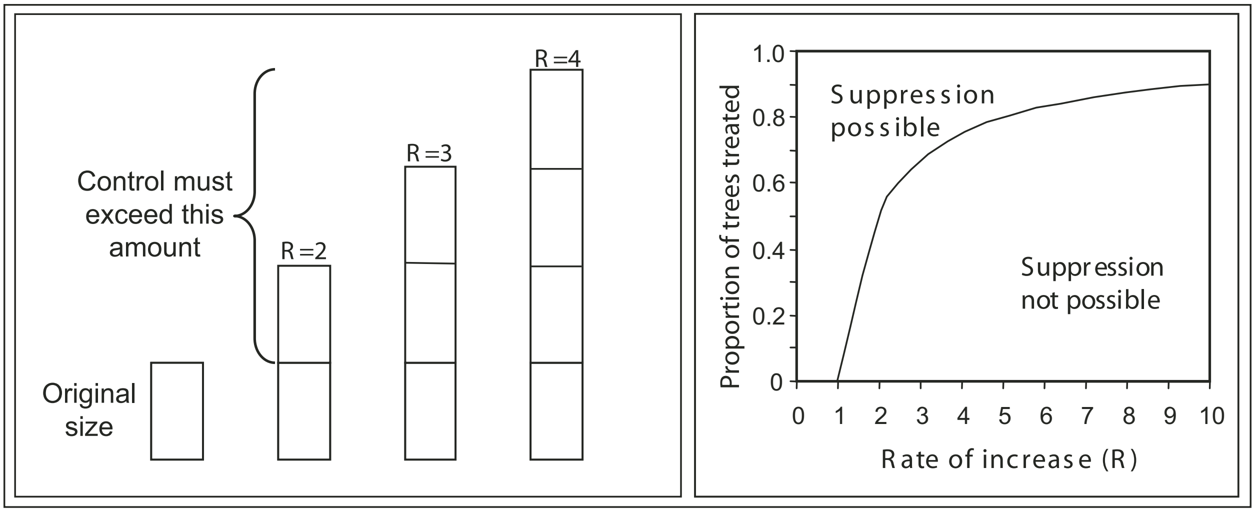

Figure 7. "Rule of thumb" for calculating what proportion of currently infested trees in an area need to be removed to keep the population static (left) and to control the infestation (right).

The diagram on the left is an illustration of the general concept. Here the first bar designates the size of the current infestation, in terms of the numbers of infested trees. The next three bars illustrate the size of the potential infestation next year provided that it doubled, tripled or quadrupled. One-half to three-quarters of the infested trees have to be removed just to keep the infestation from growing. If we want to suppress the infestation we need to remove a higher proportion of the trees. This concept is summarized in the diagram on the right. The situations where suppression of infestations is possible, given specific rates of increase in the number of infested trees, are above the curve. For example, if the average yearly rate of increase were 3, we would need to treat more than two-thirds of the infested trees each year in order to suppress the infestation. The line between suppression possible and not possible defines the number of trees requiring treatment to maintain the infestation at a static level (Fig. 7). It should be noted that use of this approach for decision-making requires good survey estimates of the number of currently infested trees.

Modelling Tools

If an infestation is not controlled at the incipient stage it can quickly accelerate to an epidemic. At this stage scattered single infested trees soon form small groups and eventually the small groups fill in to become a continuous infestation. As an epidemic grows, resource management decision-making becomes more complex. Single-tree treatments become less important and block harvesting directed at removing as many infested trees as possible is the main tactic. Infestations tend to advance in the general direction of the prevailing wind. The epidemic becomes analogous to a slow moving fire and is treated in a similar manner. Harvesting is directed at the moving front of the epidemic where the highest numbers of currently infested trees exist. The objective is to reduce the population, and try to slow the spread of the epidemic. This will buy some time in which it is hoped that unfavorable weather conditions will cause a decrease in the beetle population, or at least provide some time to recover more of the dead trees while the wood is still usable.

A point is reached where there are not enough resources to aggressively treat all of the infested trees. Strategic decisions need to be made on where to focus resources. Some of the important considerations are:

- What is the effect of this epidemic on the future timber supply? (See Pedersen 2004.)
- Where should different beetle management strategies be applied? (See Hall 2004)
- Does altering the cut level provide useful ammunition for reducing the beetle epidemic?
- What are the socio-economic implications of this epidemic?
- At what point do we decide that the fight against the beetle in a particular area is futile and focus on reducing non-recoverable losses? (Shift from suppression to salvage strategy.)
- What is the shelf life of the killed trees and how can harvesting be optimized to minimize non-recoverable losses?
- What are the other resource implications of this epidemic and subsequent harvesting?
- What will become of the stands that have been attacked by mountain pine beetle?
- In suppression strategy areas, where should blocks be placed, and what size should they be to achieve the maximum population reduction?
- How much effort should be put into beetle management, and what are the most effective tactics in different circumstances of topography, stand types, and beetle conditions?
- Would improved detection help the beetle management effort?
- Do any of the policy rules cause difficulties for beetle management?
- What is the effect of climate change on mountain pine beetle epidemiology?
- Can the epidemic spread further into Alberta and into the boreal forest?

We believe the best way to approach this multitude of questions is through modelling. The Canadian Forest Service has been transferring knowledge about the mountain pine beetle into models for the past few decades (e.g., Shore and Safranyik 1992; Safranyik et al. 1999; Riel et al. 2004). More recently, we have developed a spatially explicit, landscape level, mountain pine beetle model (SELES-MPB) in collaboration with Dr. Andrew Fall (Riel et al. 2004; Fall et al. 2004). Using this model, the spread and impact of the mountain pine beetle can be examined under different management and climate scenarios. The model can be set up to address many of the questions listed above, or to output variables that will serve as inputs to other models more specifically designed to answer these questions. This topic will be covered in more depth in Riel et al. (2004) and Fall et al. (2004).

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