Collaboration for Environmental Evidence

SYSTEMATIC REVIEW No. 46

WORKING TITLE: What management practices are effective in preventing an infestation of Mountain Pine Beetle in Colorado's front range forests?

DRAFT REVIEW PROTOCOL

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COVER SHEET

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1. BACKGROUND

The mountain pine beetle, *Dendroctonus ponderosae*, is a species of bark beetle native to the forests of western North America, from northern Mexico to northwestern British Columbia in Canada. The abundance of mature age class timber in the inventory, and a trend to warmer, drier summers and less frequent extreme cold winter temperatures, can combine to alter the balance between insect and host in forest ecosystems (Figure 1).

Mountain pine beetles colonize most native pines within the beetles range in North America, particularly ponderosa pine (*Pinus ponderosa*), lodgepole pine (*Pinus contorta*), sugar pine (*Pinus lambertiana*), and white pines, and also common non-natives such as Scots pine (*Pinus sylvestris* L). Under typical endemic or low population levels and during early stages of an outbreak, attacks are limited largely to trees under stress from injury, poor site conditions, fire damage, overcrowding, root disease or old age. As beetle populations increase, all mature host trees in the outbreak area are susceptible to attack.

The beetles kill the trees by boring through the bark into the phloem layer on which they feed and in which eggs are laid. Pioneer adult female beetles initiate attack, producing pheromones and releasing host volatiles as they bore into the bark and begin egg gallery construction, a process which attracts other beetles and result in the mass attack necessary to overwhelm tree defenses. The trees respond to boring with the release of resin at the site of attack and with a secondary increase of resin flow by tissue surrounding the

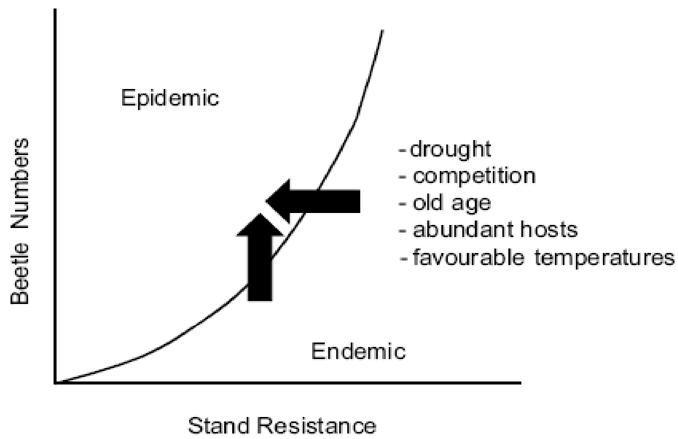


Figure 1. Factors contributing to mountain pine beetle shift from endemic to epidemic populations. The vertical arrow represents increase in beetle population and the horizontal arrow represents a decrease in stand resistance. The curved line is the threshold between endemic and epidemic populations.

Source: Shore *et al*. Principles and Concepts of Management. In: Safranyik, L.; Wilson, B. 2006. The Mountain Pine Beetle: A Synthesis of Biology, Management, and Impacts on Lodgepole Pine. Canadian Forest Service, Natural Resources Canada, Pacific Forestry Centre, Victoria, BC, Canada.

wound, which can discourage or kill the beetles. Rapid colonization can exhaust these defenses. Additionally, beetles carry blue stain fungi which, if established, block the tree's resin response. Successfully mass attacked trees are usually overwhelmed within 1 to 2 days as the phloem layer is damaged enough to cut off the flow of water and nutrients. In the end, trees starve to death, and needles of the crown begin to fade from green to yellowish to red over time.

Like the initial attack process, attack densities and competition for resources under the bark by developing immature stages is regulated by chemical cues. In addition to attractant or "aggregation" pheromones, beetles also produce anti-aggregation pheromones. The attack of a single tree can shift to neighboring trees as the number of responding beetles increases and the concentration of anti-aggregation pheromone increases. Outbreaks continue to expand to adjacent susceptible trees if the beetle numbers are sufficiently high. The resulting damage can be easily seen even from the air in the form of an increasing number of trees with reddened needles.

Impact – Mountain pine beetle has historically been the most damaging of the bark beetles in western conifer forests, in part owing to their relatively broad array of pine hosts and the extent of potential hosts. Although this beetle typically produces only one generation per year, its population numbers and the accompanying damage can grow quickly. According to the USFS, for example, in 1990 they were responsible for the death of 289,800 trees across all host species totaling 6.5 million cubic feet over 186,600 acres in the state of Washington. In 1991, 298,400 trees were lost totaling 5.6 million cubic feet over 155,422 acres. The cumulative area of lodgepole pine forests in Colorado where mountain pine beetle activity was detected in aerial surveys was about 1 million acres through 2006. In 2007, that number increased to 1.5 million acres. In British Columbia, where lodgepole forests are more contiguous than in the western U.S., the B.C. Ministry of Forests and Range reported over 24 million acres of lodgepole pine affected by mountain pine beetle in 2007. Outbreaks can last for more than ten years, and the majority of the mature, large diameter trees in the outbreak area will be killed. Outbreaks of mountain pine beetle have been recorded in the west since 1894. Mountain pine beetles are generally in an outbreak or epidemic condition on at least one of their hosts somewhere in the west.

Management – Methods aimed at addressing the existing or immediate threat of outbreak are commonly referred to as direct control tactics (e.g. spraying, felling, burning) and those focusing on aspects of stand conditions and reducing the risk of future outbreak are often referred to as indirect involving vegetation management practices. It seems possible to prevent infestation with pheromone treatments and penetrating sprays on individual, high value trees such as those in campgrounds and near houses, but they need to be applied before the tree is infested and the cost of such treatments is prohibitive for any large-scale application. Some questions remain about what economically viable methods can successfully be implemented to control an infestation at a large scale.

Mountain pine beetles are a natural part of North America western ecosystems, and for this reason will never be completely eradicated. Nor should they be, as they provide essential ecosystem services from promoting nutrient cycling processes to providing wildlife forage, which are important for forest health and biodiversity of both flora and fauna. As such, the death of a few trees over time in a given area is to be expected and does not necessarily signal the beginning of an outbreak. A variety of natural enemies of mountain beetles, including predatory insects and birds and pathogenic organisms, contribute to keeping beetle population numbers low.

To help maintain mountain pine beetles at their normal levels, predisposing factors for outbreak need to be identified. Some of these, such as environmental stresses, are not possible to control. However, many stresses are related to stand management practices. Beetle infestations have been observed in association with certain stand and site conditions, such as high stand density index and low site quality index, which has implications for developing vegetation management strategies. For example, forest stands and landscapes with little heterogeneity result in large contiguous areas susceptible to insect outbreaks. At the beginning of the twentieth century less than 20 percent of lodgepole pine forests were in age classes susceptible to mountain pine beetle infestation compared with over 50 percent of today's forests (Taylor and Carroll 2004).

When a mountain pine beetle outbreak is small, it may be stopped by thinning the stand at the edge of the outbreak. This is because outbreaks expand on a tree to tree basis where the incoming beetles switch from a recently attacked-stem to the next largest tree. Temperature and airflow changes that occur when a stand is opened up may alter chemical signals and beetle behavior. More importantly, the risk of infestations may be reduced by reducing the susceptibility of stands across the landscape through vegetation management (e.g., mechanical thinning, prescribed fire) that increases the vigor of the residual stand.

However, the degree of treatment success and the social acceptance of some of the vegetation management practices still remain unknown, especially at a large scale. Some examples of silvicultural treatments and vegetation management practices used to minimize stand stresses and maintain vigorous growing stand conditions include (adapted from Berryman 1986):

- Choose tree species or genetic stock that are adapted to the area on which they'll be planted
- Harvest trees in a way that mimics natural processes, such as cutting small patches to mimic a low-intensity fire (for pine and larch management)
- Remove diseased and unhealthy trees and logging debris, and minimize damage to standing trees.
- Salvage logging is fine for beetle-killed trees except in root disease areas where that could increase the severity of Armillaria and Annosus root diseases.

- Encourage diversity in species and age classes
- Use thinning, fertilization, prescribed fire, etc. to maintain stand diversity and vigor
- Prevent trees from becoming over mature by harvesting on time
- Patch cutting 6 to 10 acre blocks every few years and managing these as small even-aged stands helps keep the total number of older trees low and creates a variety of age classes that discourages mountain pine beetle attack. It has additional benefits for wildlife by creating small openings and edges. This may not, however, be a good strategy if trees at the edges of the cut are heavily infested with mistletoe and the species to be planted or naturally regenerated is the same species.

A comprehensive analysis review, applying Evidence-Based Management principals, of effective management practices aimed to successfully control MPB infestation is the main focus of this review.

2. OBJECT OF THE REVIEW

2.1 Primary Question
What management practices are effective in preventing an infestation of Mountain Pine Beetle in Colorado's front range forests?

2.2. Secondary Questions
- Which of the identified practices are socially acceptable and ecologically sustainable? -
- What fuel management activities should be undertaken?
- What to do with the new vegetation conditions after an epidemic and what would result in a situation that increases resiliency for the future?

3. METHODS

3.1. Search Strategy
The following electronic databases and web searches for organization libraries will be search to identify relevant studies:

- CAB Direct – Archive of summaries of the world's agricultural and applied life sciences literature www.**cabdirect**.com
- http://catalogue2.nrcan.gc.ca/html/Metafore2/English_MultiLIS/Welcome3.html
- http://mpb.cfs.nrcan.gc.ca/publications_e.html
- Google Scholar http://scholar.google.com
- Forest.Foward website – The web site covers the Natural Resources Canada-led Forestry Component of their Mountain Pine Beetle Program
- Canadian Forest Service Library

- US Forest Service Library http://fsinfo.fs.fed.us/cgi-bin/gw/chameleon
- Libraries at universities with Forestry and Forest Entomology Programs (M.S. and Ph.D. Programs)
- Web of science http://scientific.thomsonreuters.com/ (recommended by CEBC)
- Scopus http://info.scopus.com/overview/what/ (recommended by CEBC)

Search terms to include:

- Mountain Pine Beetle
- *Dendroctonus ponderosae*

Note: If the review panel thinks that we might get too many hits including irrelevant studies, we should come up with some terms that will limit the search.

3.2. Study Inclusion and Exclusions Criteria

- **Relevant subject.** The subject is MPB. The review will include all studies on MPB in North American habitats. In particular coniferous forests dominated by Ponderosa Pine, Lodgepole Pine, Scots Pine, and/or Limber Pine.

- **Timeframe.** The review will include studies from 1980-present. However, reviewers will also track down references that appear in the literature to relevant earlier research.

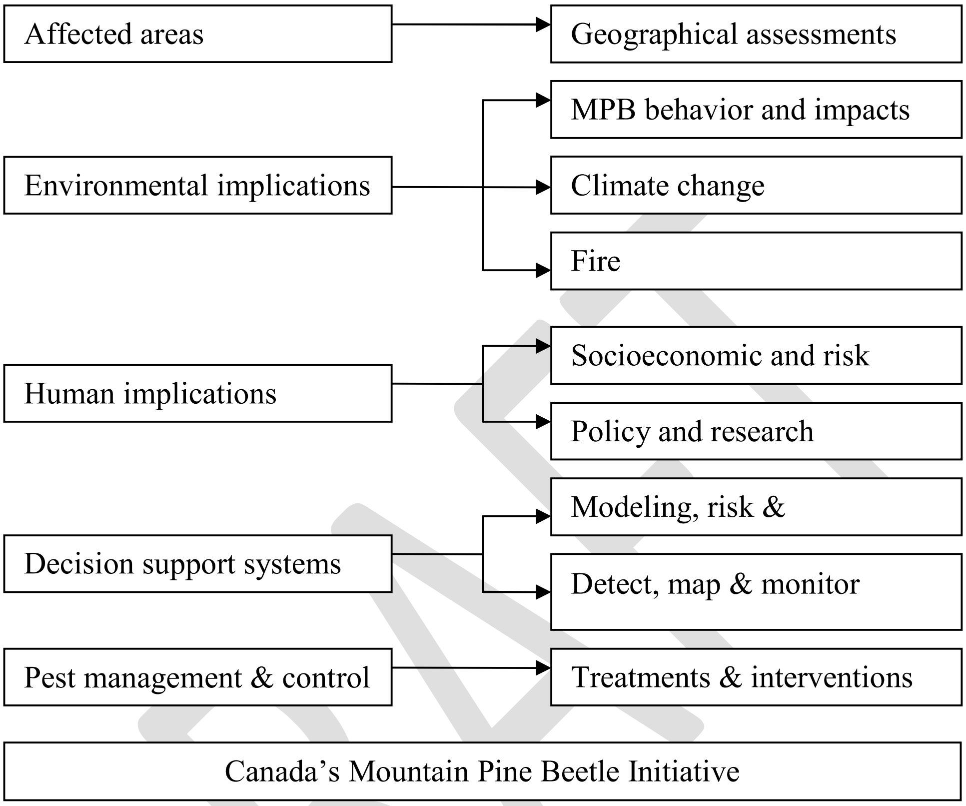
- **Types of intervention.** The review will initially include all interventions of vegetation management practices, even if they do not appear in peer-reviewed literature; as well as follow up treatments as they could alter the effectiveness of the initial intervention.

- **Types of comparator.** The intervention, where possible, will be compared to an unmanaged control where no intervention has taken place, or where it is normal practice for that intervention to take place. Comparisons will be included that are temporal for the same area, or spatial where the experimental area is directly compared with another untreated area. The review will also include studies that show a dramatic change following intervention in uncontrolled experiments, in accordance with the hierarchy of evidence.
    - Replicated randomized experiments
    - Before-after control-impact (BACI) studies
    - Observational studies
    - Expert opinion

- **Types of outcome.** The primary outcome is change in the MPB population levels.

- **Types of study.** Studies and management practices investigating the control of a MPB infestation. Considered studies should provide either quantitative and/or qualitative information. Outcomes will be categorized into quantitative measurement and qualitative measurement.

An initial literature search shows the following major categories into which MPB-related studies can be classified:



[Review panel will to decide what literature categories we adopt and which ones we drop]

3.3. Study Quality Assessment
Studies will be evaluated based on one of the following suggestions.
a) Study methodological quality will depend on the type of methodology comparator, with the greatest weight given to replicated randomized experiments and less to observational and opinion studies.

b) The quality of the study will be scored according to the hierarchy of evidence[1] adapted from models of the systematic review process used in medicine and public health

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[1] A 'hierarchy' of evidence is commonly used for such appraisal, where the findings of studies using strict experimental designs are accorded greater weight than those that have no comparison or 'control' elements. The authors have modified this hierarchy for use in conservation in Apendix 1. Studies that do not meet the required quality standards are likely to be excluded. The data from acceptable studies are then combined in a meaningful way, the result being a more powerful and reliable assessment of the effectiveness of the action than might be obtained from a single study or non-systematic review.

(Stevens and Milne 1997; Pullin and Knight 2003) reviewers will independently assess each accepted article, filling in an assessment form. Any disagreement will be resolved by consensus and referred to a third reviewer if required. Alteration of the protocol may be necessary once the review is underway.

c) The methodological quality of all the eligible studies identified will be assessed against a checklist of criteria [TBD by reviewers]. As no studies are being excluded from the review at the inclusion/exclusion stage due to the study quality a variety in the methodological quality of studies is anticipated.

3.4. Data Extraction Strategy

Reviewers will assemble information in a master spreadsheet [create a common one for everyone to use], recording qualitative and quantitative aspects of the studies. Three scenarios to consider about data extraction that reviewers need to decide:

a) All studies included at full text will be read by two member of the review
b) One reviewer will extract data with a subset being reviewed by another to ensure accuracy.
c) No need to involve more than one reviewer for each study

3.5. Data Synthesis

The synthesis of the data will include summary tables of study characteristics, study quality and results. The synthesis will focus on evidence from literature regarding to specific treatments and the outcomes of those.
The reviewers (or a set of them) will quantitatively analyze the data when possible; it will depend upon the nature of extracted data. Meta-analysis[2] will be done when feasible. The group will draw conclusions about the similar and different effects of treatments and highlight areas where further research is needed.

4. POTENTIAL CONFLICTS OF INTERESTS AND SOURCES OF SUPPORT

There are no known conflict of interests.

The US Forest Service has provided the funding and staff time support for this review. The Society of American Foresters has also contributed with staff time and office related resources.

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[2] Meta-analysis – in statistics, *meta-analysis* combines the results of several studies that address a set of related research hypotheses.

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Appendix 1. Hierarchy of quality of evidence based on the type of research undertaken.

Category	**Quality of evidence – Medical**	**Quality of evidence – conservation**
I	Strong evidence obtained from at least one properly designed; randomised controlled trial of appropriate size.	Strong evidence obtained from at least one properly designed; randomised controlled trial of appropriate size.
II-1	Evidence from well designed controlled trials without randomisation.	Evidence from well designed controlled trials without randomisation.
II-2	Evidence from well designed cohort or case-controlled analytic studies, preferably from more than one centre or research group.	Evidence from a comparison of differences between sites with and without (controls) a desired species or community.
II-3	Evidence obtained from multiple time series or from dramatic results in uncontrolled experiments	Evidence obtained from multiple time series or from dramatic results in uncontrolled experiments.
III	Opinions of respected authorities based on clinical evidence, descriptive studies or reports of expert committees	Opinions of respected authorities based on qualitative field evidence, descriptive studies or reports of expert committees.
IV	Evidence inadequate owing to problems of methodology e.g. sample size, length or comprehensiveness of follow-up or, conflicts of evidence.	Evidence inadequate owing to problems of methodology e.g. sample size, length or comprehensiveness of monitoring or, conflicts of evidence.

Source: Pullin, A.S. and Knight, T.M. Support for decision making in conservation practice: an evidence-based approach. *Journal for Nature Conservation* 11: 83-90; 2003.