Colorado Mountain Pine Beetle Infestation: Causes, Consequences, and Cures

By Allison Frederick, Environmental Writer, Green Business Brand Promoter
INTRODUCTION

The Mountain Pine Beetle infestation in Colorado’s mountains has killed more than 1.5 million trees in the past decade adversely impacting Colorado’s ecology, economy, and aesthetic. The consequences of the infestation shall be extensive, long-term, and costly in many respects. This review explores the etiology of the infestation, responses to the infestation, environmental and economic impacts, and offers a multi-pronged approach for present and future management.

METHODOLOGY

A significant amount of the reviewed literature is sourced from official government- or university-produced literature, including National Renewable Energy Laboratory (NREL), U.S. Forest Service, Colorado State University, Environmental Protection Agency, Colorado Governor’s Energy Office, and United States patents and publications. The remainder of resources for this review derive from peer-reviewed literature as it pertained to forest management and the mountain pine beetle.
THE NATURE AND EXTENT OF THE INFESTATION

For more than 150 years, the state of Colorado has enjoyed densely-colorful evergreen forests and subsequently benefits from substantial tourism revenues relating to its abundant forests and National Parks. However, since 1998\(^1\), Colorado has suffered from a severe infestation of Mountain Pine Beetle (MPB) or *dendroctonus ponderosae hopkins*, which has since reached epidemic proportions and is devastating the state’s scenic landscape.

Lodgepole pine (*Pinus contorta*) are tall, thin, deeply colored evergreens. *Pinus contorta* means “twisted pine.”\(^2\) The subspecies found in the Rocky Mountains of Colorado is *latifolia*. Lodgepole pines thrive in abundant sunlight and in cold, dry climates\(^3\) such as those conditions found in Colorado.

The current epidemic is not the first time Colorado pine has suffered from an infestation. A less severe outbreak of MPB in the mid-1970s\(^4\) proved to be relatively self-limiting, possibly due to, in part to less extreme weather conditions than what co-exist with today’s epidemic.

By 2009, sixty-eight percent of the Colorado lodgepole pine forest were infected by MPB (Figure 1).
Today, residents, scientists, and government officials remain concerned because infestation is now spreading to other prevalent Colorado pine species, including Ponderosa Pine and spruce and fir trees. Management approaches to the infestation have ranged from no intervention to intense pesticide spraying. Yet the reason the rate of infestation has slowed among lodgepole pines appears to be because there simply aren’t many more lodgepole pines to be consumed. It is estimated that it will take fifty to one hundred years before the landscape aesthetically recovers.

The infestation is commonly referred to in both scientific literature and the media as being caused by the mountain pine beetle. However, the damage to the pine forests is not actually caused by the MPBs themselves, but by the fungi spores living on the beetle’s body. The complex interaction between the mountain pine beetle and the fungi spore is an example of a small microcosmic relationship exerting large scale impact on a larger ecosystem. This example hints at the difficulties of not only identifying all the
contributing factors of the pine beetle epidemic, but trying to sustainably manage the situation.

How did the current infestation progress from a relatively benign level to a devastating epidemic? The cause of the current MPB epidemic, like any epidemic, is multi-faceted (Figure 2 on next page).
CAUSES AND CONSEQUENCES OF THE MOUNTAIN PINE BEETLE INFESTATION
This epidemic appears to be the result of a combination of both natural weather phenomena creating unfavorable conditions for Colorado forests and the result of well-intentioned, but perhaps short-sighted, human intervention with unanticipated consequences.

**Etiology of the Infestation**

The first contributing factor cause appears to be natural. A four-year Colorado drought, beginning in 1998, is partially responsible for the waning health of the lodgepole pine stands making them increasingly susceptible to MPB infestation. The drought has been attributed to La Niña, a period of oceanic cooling in the Pacific Ocean which began in 1998. The oceanic cooling effect of La Niña reduced the amount of tropical rain precipitation, leading to drought conditions in states like Colorado. Less water to Colorado forests dried out the older, more susceptible lodgepole pines decreasing their overall health and making them a prime food source for the MPB. This had the effect of exponentially increasing the rate of infestation by MPB. For example, in 2002, only four million acres of forests were inflicted with pine beetle. That figure jumped to over ten million acres (representing a 250% increase) in just 12 months.

The second major factor contributing to the MPB epidemic appears to be related to a cascade of human decisions spanning over nearly two centuries. Human activities and intervention, collectively contributed to something called “increased canopy density” of Colorado’s pine forests. In turn, increased canopy density adversely affected the health of the lodgepole pines and made them greatly susceptible to MPB. These
human activities and interventions include forest fire suppression, proliferation of the livestock grazing and logging industries, and, rather ironically, the banning of logging activities in certain areas of government-owned forests.

A 1985 study from Oregon State University, demonstrated that the factor most effecting lodgepole pine forest health was the density of the pine forest canopy. The study found that dense forests cannot obtain ideal amounts of photosynthesis needed to maintain health and produce enough carbohydrates to meet growth needs and defensive needs through production of allelochemics. Proper levels of photosynthesis keep lodgepole pines relatively immune from MPB and the fungi spores they carry. Their experiments showed that a thinner canopy was even more valuable than nitrogen fertilization.

Historically, naturally-occurring fires (usually caused by lightning) helped keep the forests in an overall healthy state by thinning the forests canopy, which meant that the understory (the low-lying layer of vegetation beneath a forest’s tree tops) and the canopy had sufficient exposure to collect light for photosynthesis. Non-indigenous people such as European settlers, however, focused efforts on fire suppression. Rather than being nomadic as many native people were, Euro-settlers inhabited the land on a relatively permanent basis. Fire was now considered a danger because it could destroy man-made structures and threaten crops and livestock; whereas native peoples simply migrated away from fires.

As a result of the behavior of European settlers, the composite of Colorado forests today differs significantly than the pre-European settlement forests. Pre-European-settlers in the American western forests (prior to the 1600s) hosted only 40 to
50 trees per acre. By 2002, many forest slopes in the ponderosa-lodgepole pine strata hosted 200 to 400 trees per acre – a 500%-1,000% increase in forest density.\textsuperscript{13}

Livestock and livestock grazing of Euro-settlers also significantly contributed to the increased density of American western forest land.\textsuperscript{14} Livestock grazing minimizes grasses and leaves on shrubs which normally provide a fuel source for forest fires triggered by lightning strikes, thus again reducing the incidence of naturally-occurring forest fires; the net effect being increased density to forests and decreased photosynthesis among the pine. Livestock grazing did plateau during the late 1800s and early 1900s due to a massive drought in the area, making it difficult for ranchers to maintain large populations of herd.\textsuperscript{15} However, this livestock grazing setback failed to relieve the forests’ increasing canopy density because a new threat quickly emerged: logging.

Logging was reaching new heights of productivity at this time and newly cleared lands gave young trees an opportunity to take root and grow. At first glance, this may seem like a good thing, however, an ecosystem is incredibly complex and human intervention often has unforeseen consequences. In Colorado’s case, and indeed in the American western forest lands in general, poorly managed, large-scale logging efforts over the course of a century collectively produced a new, single generation of young trees. The net effect was large forest acreage, all of the same relative age. A forest stand lacking diversity in age is more susceptible to insect infestation than an integrated, multi-generational forest. This is, yet another, major contributor to Colorado’s pine beetle epidemic.
Responses to the Infestation: Case Study: Summit County, Colorado

Summit County is a 620 square mile mountainous territory located approximately 70 miles due west of Denver. Summit is one of the numerous counties hardest hit by the infestation of mountain pine beetle (MPB) in the last decade. Summit County is home to well-developed, high tourist mountain communities including Breckenridge, a popular, nationally-known recreational destination.

Non-Intervention

In the early years of the epidemic, non-intervention had been the dominant approach especially near the highly-visible terrain slopes along the interstate passing through Summit County. As such, the county’s response of non-intervention to the infestation has been heavily scrutinized. Interstate 70 traverses the county shuttling tourists and city residents up the mountainous passes to this visually stunning recreational paradise. However, since 2002, visitors have been greeted by copper-tinged and ash-grey colored skeletons of what was once a magnificently dense evergreen forest. Reasons for non-intervention include apathy due to a comparatively low human population as well as a lack of residential and commercial infrastructure, excessively steep terrain slopes, and the high costs association with removal of pine beetle killed trees.

Another major obstacle to responding proactively and sustainably to the MPB epidemic is the decline in the national and regional economy shortly after the worst
effects of the MPB epidemic hit. The peak years of the infestation were from 2002 – 2008 and the US economy began to rapidly decline in 2008. Governments brought in less tax revenue, and costs to try to contain the pine beetle epidemic increased with no foreseeable end in sight. With the prohibitively high costs for dead tree removal and with 1,046,000 acres in Colorado afflicted by the infestation, removal costs could range anywhere from $31 million to $2 billion.\textsuperscript{16}

In spite of prohibitive costs associated with addressing the problem and the severity of present conditions, non-intervention is no longer an option. Ignoring or “watchful waiting” of the problem has already proven itself to exacerbate the epidemic. Furthermore, non-intervention could theoretically decimate the state’s tourism industry as no one will want to camp, hike, or otherwise vacation in a dead forest.

\textbf{INSECTICIDE}

Insecticide may seem like a logical form of intervention. However, both short-term and long-term consequences of such an approach must be considered. Grand County, Colorado, the northern-neighboring county to Summit, provides residents with an insecticide products information guide.\textsuperscript{17} The guide recommends use of carbaryl (trade name Sevin). Carbaryl is a widely used insecticide that affects over 100 insect species\textsuperscript{18} including MPB. Like many pesticides, much of the pesticide’s potential harm comes from indiscriminate application and disposal.\textsuperscript{19}

Carbaryl is a neurotoxin interfering with the normal performance of achetylcholine, a neurotransmitter that regulates heart rhythm and other neuromuscular movements. According to the Grand County product guide, carbaryl is not a restricted
use pesticide, meaning that it does not need to be applied professionally. A review of the fact sheet, therefore, might lead one to conclude that carbaryl is a relatively safe and benign pesticide with relatively little risk to humans. However, in stark contrast to the Grand County product guide, the Environmental Protect Agency's Registration Eligibility Decision report explicitly states that carbaryl is “likely to be carcinogenic to humans.”

The same report warns that human risk relates to the application and handling of the pesticide of which it is much more likely that an untrained, general public person applying carbaryl to their trees is more likely to accidentally expose themselves to the toxin. Bayer CropScience company, the technical registrant of carbaryl, voluntarily eliminated application methods of its product including dry flowable (water dispersal granules) and back pack sprayers. This might suggest that Carbaryl should, in fact, require professional application.

In light of this information, perhaps more thorough, careful studies should be conducted in fish, bird, mammal, and beneficial insect species to examine the consequences of food chain concentration and carbaryl bioaccumulation prior to green lighting its standard use for preventing MPB.

BEETLE KILL TREE REMOVAL

Another response to the infestation is simply to remove the waste produced by MPB. However, there are considerable challenges associated with this response. In 2007, Summit County paid between $300 and $2,000 an acre to logging companies to clear trees killed by MPB. These costs influence decisions on which areas are to be cleared, particularly as the current national and regional economy is weak and all
government budgets have been significantly reduced. Furthermore, due to the high cost of tree removal, Summit County government services and other entities such as the U.S. Forest Service are focusing their timber clearing efforts in areas along roads, utility lines, recreational trails, and in other areas of human residence. These areas may appease public outcry but may not be the more efficacious use of resources.

**CONSEQUENCES OF THE INFESTATION**

**PHYSICAL CONSEQUENCES: FOREST FIRES, SOIL EROSION AND WATERSHED CONTAMINATION**

Adverse consequences of the dead tree harvesting effort include soil erosion and watershed contamination. Uncontrolled, unintentional forest fires not only ruin wildlife habitat, kill animals and people, cause millions of dollars in property damage, and increase the costs of property insurance (and in many cases, negate the property owners’ ability to obtain property insurance), but these fires also contribute to soil erosion.

It isn’t uncommon for the Colorado slopes to be as steep as 70 degrees, which means gravity plays a greater role in changing the landscape. Fallen trees and understory, all charred by fires, lead to soil erosion, which runs into streams during storms causing water contamination. Increased sediment in the rivers leads to shallower bodies of water (particularly in Colorado’s semi-arid climate where most of the streams are shallow or perennial to begin with). Shallower streams and more sediment can lead to greater eutrophic properties and lower oxygen levels. Additionally, Colorado
provides water to its own residents and eighteen additional states, yet its annual precipitation is only 17 inches a year. Sediment, fire retardants, and insecticides used to combat pine beetle infestation end up in this critical water source causing further problems for water treatment facilities and distribution.

The year 2002 was not only a bad year in terms of exponential expansion of pine beetle infestation, it was also a bad year in Colorado for forest fires. “Following the Buffalo Creek and Hayman fires, Denver Water has spent more than $10 million on water quality treatment, sediment and debris removal, reclamation techniques, and infrastructure projects.” The Denver Water Board has created a new partnership to try to address these mounting issues through a U.S. Forest Service and Denver Water Watershed Management Department called “From Forests to Faucets.” This partnership combines financial resources, an exchange of information, and the development of strategies to the 14.5 million acres managed by the Rocky Mountain Division of the U.S. Forest Service, within which, 90 percent of these lands are located in watersheds.

In addition to watershed contamination, landslides, a product of soil erosion, destroy other wild habitat and human property. Many of Colorado’s forest roads are unpaved and are particularly susceptible to erosion. The Hayman Fire of 2002 was the largest forest fire in Colorado’s recorded history effecting 4 counties (destroying 138,000 acres) and causing over $40 million dollars in property damage. Subsequent landslides from burned areas resulted in the closure of the unpaved State Highway 67. This road is most often used for providing recreation access to the popular South Platte River and to local residents. Yet the repairs to this highway that were required to reopen
the highway cost $11 million.\textsuperscript{30} Fire suppression of the Hayman fire cost more than $42 million and there was a property loss of 600 structures, including 132 residences.\textsuperscript{31}

**Economic Consequences: Tourism Revenues, Property Values & Taxes**

The existing and future aesthetic damage to the state of Colorado and its subsequent economic consequences could be unprecedented. As seen in Figure 3, the color landscape of Colorado forests range from the healthy green, to the diseased copper red and brown, to the ashen grey of a dead forest grove. While observing a green grove of logdgepole pine, one may erroneously assume that the grove is unaffected by the MPB infestation. However, it can take up to three years for an infected tree to change from green to copper or brown.\textsuperscript{32}

![Figure 3](image-url) Areal view demonstrating the extent of the impact.
The MPB infestation will likely have sizable adverse consequences to Colorado’s economy. Tourism is the state’s 2nd largest industry employing more than 140,000 people and generating considerable tax revenues. Certainly a majority of these visitors to Colorado are intent on enjoying Colorado’s beautifully, lush forests, mountains, and rivers. The question remains as to whether tourists will continue to visit Colorado and spend money if those forests die and vanish over the next 5 to 10 years.

Private property tax revenues will also be likely to decline substantially as mountain home residences lose aesthetic value to the MPB infestation. Few homeowners will want to purchase a home or vacation home in a dead forest community. Existing mountain home owners certainly will not be able to sell their homes if their property looks like an ashen graveyard. These and other economic consequences could be far-reaching and long-term.

Despite the potential to use the dead lodgepole for consumer products such as lumbar or as an energy source, much of the wood that was harvested from the infestation was rather unfortunately burned on site. Due to economic challenges relating to distribution of the beetle kill wood, it was far more economical to burn the harvest on site than to haul it somewhere for processing.

Now that we have a fairly comprehensive understanding of the MPB epidemic, its etiology, and consequences, let’s now evaluate some potential solutions to this chronic problem.
POTENTIAL SOLUTIONS FOR THE INFESTATION

Options for addressing the infestation itself are somewhat bleak. Of the two primary causes of the infestation, the first, La Niña, is a globally influenced, not well understood, cyclical weather pattern. The second cause, excessive canopy density, was certainly within man’s influence, but the opportunity for prevention has largely past and without today’s perspective of the long term consequences of canopy density, would have been difficult to anticipate. At this point, we are essentially left to employ a “making lemonade out of lemons” approach.

For the state of Colorado, the development of a sustainable forest product market program with a lifespan beyond that of the time it will take to address the current waste issue (i.e. the beetle-kill) is not overly-viable. However, the death of nearly 1.5 million lodgepole pines in conjunction with the seemingly eminent shift of the beetle to other tree species, such as Ponderosa Pine, indicates that Colorado does have a significant amount of waste that must be removed. Failure to promptly and efficiently remove the beetle-kill represents human safety issues, a threat to Colorado’s tourism industry, and a threat to wildlife habitat primarily through the risk of forest fire.

An opportunity to minimize future devastation of Colorado forests through the protocols outlined herein does exist. It is, perhaps, more important to educate and persuade the public to adopt a paradigm of sustainable, incremental interactions with the environment. Such persuasion should lead to political change through community driven initiatives promoting sustainability; rather than the reactive extremism that has dominated social consciousness up until this point.
Colorado’s evergreen trees are relatively small in diameter, dry, and slow growing. These qualities make Colorado a poor choice for lumber industry operations compared to neighboring north-west states. In fact, many are surprised to discover that Colorado imports 90 percent of the wood it uses. Considering that Colorado’s logging industry prospects are limited, an effort to offer significant financial incentives to organizations that demonstrate adherence to sustainable practices should be attempted. Such an effort can bring new jobs to Colorado, stimulate the economy through increased economic activity, and will help residents address this considerable problem with the intent of minimizing or preventing future infestations.

**ACTION:** **INSECTICIDE APPLICATION**

A first step towards resolution is to protect healthy trees. One way to do this is to consider using insecticide or insecticide-like products on unaffected trees bordering infected areas. While trees that border inflicted areas could be sprayed, in light of reports from the Environmental Protection Agency (EPA) regarding carbaryl and in consideration of the enormity of this current infestation, it is recommended by this review to change the status of carbaryl from an unrestricted insecticide to a restricted pesticide as it applies to this situation. Taking the pesticide off the shelves of consumer retail outlets can reduce risks of indiscriminate application and its subsequent adverse environmental impact, such as contaminating ground water runoff. Trained professionals will then be responsible for properly handling, applying, and disposing of carbaryl. Monitoring the effects of carbaryl application on wildlife and water sources on a regular basis is also recommended.
Another reason for this suggestion of better regulating the distribution of carbaryl has to do with questions regarding its efficacy. According to the Utah State Entomologist, Diane G. Alston, carbaryl will provide protection on the trees only for 12 to 18 months; the insecticide application is topical and effective only on unaffected trees because MPBs burrow below the outer bark to nest in the inner bark where insecticide fails to penetrate.

**ACTION: PHEROMONE APPLICATION**

A second approach to be considered is to attract the MPBs by way of pheromones applied to sticky trap paper. One report states that this practice has been employed since 1968, however, with mixed results. In a past experiment by the EPA, pheromones used to trap Douglas-fir beetle also unintentionally attracted and trapped the fir-beetle’s natural predator, a checkered beetle called *Thanasiums undatulus*. So, it is possible that this approach could be counter-productive. However, if the technology could be further investigated, perhaps it could be utilized effectively.

In the meantime, other pheromone-based products exist. In a U.S. patent application, inventors Borden and Pureswaran disclose a method of combining two chemical blends to work with pheromones which statistically trap more female than male beetles. Trapping the female beetles may be an effective approach to slowing down infestation. Pheromone traps may be easy to implement in areas with high human density where land owners, trail maintenance managers, ski resorts, and municipalities, can easily access the trees stands to apply and maintain the traps.
ACTION: DECREASING CANOPY DENSITY

A carefully managed tree-thinning campaign aimed at decreasing canopy density must be executed in healthy forests. As the University of Oregon study found, reducing the density of the forests successfully increased tree health and resistance to pine beetle by allowing the trees to access more sunlight, increase their rates of photosynthesis, and thereby increase their production of carbohydrates that not only provided nourishment for the trees, but the carbohydrates also improved the tree’s immune response in defense against the beetle. Just as Pasteur’s germ theory has been shown to be limited to susceptible hosts (i.e. those who already have a compromised immune system), insect infestation in trees similarly dominates in weakened populations. Historically, and with good reason, there has been significant public resistance towards logging and tree thinning in forested lands, but this resistance has contributed to the infestation problem we have in Colorado today.

One type of tree thinning prohibited in the county is “pre-commercial thinning.” Pre-commercial thinning is when the tree stands are thinned out while they are still young and the wood harvested is too small to be of commercial value. Lodgepole pine seedlings can spread and take root quickly, and set their own stage for a dense forest as they mature. The Colorado Timber Industry Association recommends pre-commercial thinning as a long-term lodgepole pine stand management strategy; stating the best results are achieved when thinning occurs while the forests are younger.

One objection regarding tree thinning and logging in Summit County surrounds a debate over the destruction of the snowshoe hare habitat. The snowshoe hare lives
among the lodgepole pine and is the primary prey for lynx, which are on the Endangered Species List.\textsuperscript{45} The low population levels of lynx led to a ban on pre-commercial tree thinning, which, in hindsight, appears to have contributed to the large scale death of thousands of acres of forest.

This situation illustrates the complex, often unforeseen consequences of human interaction with the environment and the far reaching effects of even well-meaning, highly educated people. In this situation, perhaps a better solution could have been to allow for pre-commercial thinning in controlled areas and then to conduct studies to ascertain the true impact of tree clearing on the hare and lynx populations, rather than institute an outright ban.

Colorado can create a logging initiative by modeling successful programs. Governing boards can include experts from the U.S. Forest Service, Colorado State University (a leading local authority in agriculture and land management), the Denver Water Board (as Colorado’s mountain watersheds provide water for a large human population), and experts from states and Canadian provinces that have already successfully implemented sustainable logging practices. Algonquin Park in Ontario, Canada has successfully managed a large sustainable management plan over the past century carefully balancing the needs and expectations of public tourism and recreation with needs of the powerful Canadian logging industry\textsuperscript{46}.

To encourage community acceptance and participation, perhaps the initiative could be packaged as a “Forest Health – Waste Mitigation” project. Contracts should be awarded only to logging companies who demonstrate a commitment to sustainable forest management, including land erosion mitigation, no onsite burning, and equipment
that is rated as having an overall low-impact on the environment. Evaluations of compliance to the terms of issued contracts can be monitored through unannounced site visits by governing officials, independent environmental impact audits by entities such as the EPA or the Wildlife Division, and company furnished reports, all of which are posted with full disclosure the Internet.

**ACTION: INCENTIVES FOR PROCESSING AND DISTRIBUTING HARVESTED WOOD**

A major challenge in logging is what to do with the harvested logs. Collecting, bundling, and transporting the harvested wood to an intermediary processor, whether it is a wood pellet factory, a paper mill, or furniture-building factory, is very costly and requires an effective infrastructure (permits, equipment, on-site loggers, truckers, and an end-consumer market). Solving this problem in an economic recession has left governmental officials stumped (pun intended).

Due to Colorado’s poor lumber industry qualities, Colorado presently lacks most of the infrastructure needed to facilitate a profitable processing and distributing mechanism of beetle-kill. For example, when pine beetle lands were cleared in Summit County, the harvest wood was piled up and left rotting. Even though residents wanted the wood, there were no or insufficient mechanisms in place to get the beetle-kill to them. Piled wood increases the risk of forest fires because the piles can spontaneously combust. Another choice the county made was to burn the harvested wood onsite to avoid transportation and disposal costs. However, burning the trees in an open air environment created unnecessary air pollution in a county that already has its highest air pollution particulate from wood burning. Figure 4 compares various sources of air
particulates (the size is expressed in the unit PM2.5) with wood burning levels at 236 versus fossil fuel combustion of 5 for Summit county. This demonstrates that uncontrolled burning of beetle-kill is not a viable option for the county.

As part of a sustainable wood harvesting initiative, new logging contracts should change past behavior by stipulating that harvested wood not be burned onsite and that
a certain percentage of the wood must be pre-processed onsite, thereby reducing transportation costs. Figure 5 illustrates the lower transportation costs for bundled and chipped wood in comparison to stumps and loose residue wood.

![Figure 5](image)

John Deere, an international company that manufactures heavy agricultural and logging machinery, recognizes the budding shift in public sentiment towards sustainable forest management and recognizes that we may be entering a new era of logging. Instead of labeling their machines as “logging machines”, which may come with a certain negative connotation, the company elected to name the machines “Energy Harvesters”, benefiting from the new goodwill of utilizing wood as a renewable energy alternative to fossil fuel such as petroleum and coal. John Deere has the motive,
resources, and experience to help local governments and forest services to maintain healthy forests through sustainable log harvesting and thinning.

![Figure 6](image-url) The patented technology of John Deere’s 1490D Energy Wood Harvester

One innovative John Deere product is the 1490D Energy Wood Harvester (Figure 6). The 1490D harvests and bundles the wood into compact units making loading and transporting easier. This machine, protected through patent technology, strives to compensate for the normally adverse environmental impact of heavy logging machinery. The lightweight tractor-like machine evenly distributes its weight along each wheel with a full gear bogie axle, wherein it averages less than seven pounds per square inch of pressure on the forest understory. This is marketed as the equivalent of a person walking on the ground.

The more lumber can be processed onsite, the less the physical burden and cost of transportation, and the greater the opportunity to utilize all the wood, even slash
(limbs and tree top residues) that are normally left behind on the forest floor suffocating the understory and serving as a fuel for forest fires. Based on 2007 rates, if the cleared wood was hauled to a Summit County disposal center (and much of it was), disposal fees for wood chips cost $1.50 per ton versus $15 per ton for intact lumber\textsuperscript{52} - representing a 10-fold savings.

This solution also allows for the creation of jobs and stimulates the regional economy. Furthermore, costs for tree removal can be transferred from the government to entrepreneurial companies.

Onsite burning should be replaced with a “community discard program.” The logging companies should be permitted significant tax breaks as compensation for allowing residents, local carpenters, and small mill companies to come to the logging site and haul away any wood debris, which normally would be burned on site for free of charge, or for a fee significantly below the market price. Opening up the wood debris removal to local citizens reduces the costs for local governments and logging companies, provides a free or inexpensive base product or fuel source to local citizens, prevents the forest understory from being choked by debris, and eliminates onsite burning, thereby reducing the environmental impact on air quality for the tree clearing effort.

**ACTION: PROGRESSIVE REFORESTATION**

Another critical component of the waste tree clearing is replanting new trees. A healthy forest is diverse in both age and tree species. Colorado’s dry climate and extreme slopes limit species diversity more than forests on both the west and east
coasts of the United States. Nonetheless, species diversity and particularly age diversity can be managed among Colorado forests. The lodgepole pines were all of similar age as they were planted following massive logging efforts in the late 1800s to early 1900s. The lack of diversity in the age of the trees predisposed the species to the beetle infestation.

Lack of tree age diversity is not a new consideration. In the 1980s, forest service entomologists began proposing solutions to diversify the age of the trees in the national forest lands in Summit, Eagle, and Grand counties. Their 1985 survey found that only 14% of the lodgepole pine in these counties was younger than 80 years. The study, which was not implemented, called for a regeneration of 9,000 acres.53

ACTION: ENCOURAGEMENT OF BEETLE-KILL PRODUCT MANUFACTURING

To address the heavy volume of salvaged wood, small to medium sized local processing facilities (even temporary facilities) must be encouraged rather than the development of large wood mills, or large wood energy facilities, which may be forced to import wood from other states in later years when Colorado wood supply returns to normal levels in order to maintain operations.

One favorable side effect of MPB infestation is that the diseased pine wood has an attractive blue hue left over from the fungus streaks. Local Colorado carpenters, manufacturers, or even artisan should be permitted low cost or no cost access to beetle-kill wood in return for manufacturing products from the beetle-kill. Beetle-kill is a perfect material for beautifully, blue-stained cabins, wood floors, furniture, and cabinets (Figure 7).
Figure 7 The beetle carries a fungus with it which is the actual cause of tree death. The only aesthetic quality of the mountain pine beetle infestation is the beautiful blue streaks of the fungus as seen here in this wood floor.

Summit county governments already provide support for these merchants by waiving a portion of local sales taxes on Colorado Pine Beetle-kill products. This type of economic encouragement is a great way to show support to the craftsman and the communities supporting them. It is also an excellent way to encourage the recycling of the wood waste. A website announcing areas where tree clearing is taking place and encouraging local wood workers to bring their own pickups and haul away felled wood is one way to address the distribution challenges of the cleared trees and encourage small business incorporation of beetle wood waste.
ACTION: ENCOURAGE OF ALTERNATIVE HEATING DEVICES

Another small, local solution for utilizing wood waste from the infestation is to provide consumer tax rebates to residential, municipal, and small commercial buildings who install or convert conventional heating devices (boilers, hot water heaters, and wood stoves) into dual chamber, combination wood and gasification systems. This tax rebate will not only significantly improve air quality by reducing air pollution from wood burning to nearly zero, but it will also stimulate the economy by encouraging consumerism, provide jobs to contractors who install and maintain the systems, and to companies selling the systems.

The burning of wood as an energy source has been a strategy employed throughout human history. However, with the exponential increase of population, careful planning and regulation coupled with advances in technology to manage wood burning emissions is necessary.

One company responded to the wood burning particulate problem by creating a high efficiency boiler. The patented technology is suitable for residential and small commercial use. The patent application presents the problem it solves as “[I]n conventional wood furnaces, after the initial burning of the fuel, a large amount of combustible gas is released. This unburned gas may account for as much as 50 percent of the wood fuel energy, and this amount of energy is unfortunately lost. A high percentage of this lost energy may be captured and used in a process called gasification. In a gasification boiler, the gases and unburned particles given off when burning (with primary air) the wood or biomass, which otherwise would pass up the flue,
are met in a secondary combustion chamber with a jet of superheated air, resulting in a torch-like combustion of these retained gases and particles at very high temperature, such as 1100 degrees F. 

This technology is marketed as the Econoburn® Wood Boiler (Figure 8), and it sells for about $8,000 USD, including shipping, sales tax, and installation. The average cost to use per year is $859, burning approximately 5 cords of wood (these figures are based on a New York home, less than 2,000 square feet, see Figure 9 for more performance figures). Double chamber combustion wood boilers and wood stoves, coupling wood burning with gasification technology is an excellent way to utilize wood as a heating source. With low emitting particulates and low carbon dioxide pollution, it is a potentially sustainable solution and should be a candidate for a tax rebate to encourage adoption.

Figure 8 an installed Econoburn™ Wood Boiler
CONCLUSION

The Colorado MPB infestation was a somewhat preventable outbreak caused by a combination of factors surrounding unfavorable weather patterns and long-term, short-sighted human interventions, some of which were well-intentioned. At this stage of the infestation, treatment options are limited and efforts must now be focused on recovery efforts to prevent future outbreaks and any worsening of present conditions. As this review demonstrates, addressing the Colorado mountain pine beetle epidemic is
complex and costly, and is riddled with both known and unknown consequences. The prevention of future or continued outbreaks depends, in part, on leniency regarding conservation efforts for species like the snowshoe hare and lynx to consider the long term impact current conservation efforts can have on an ecosystem.

Before the adoption of any policies, perhaps it should be asked, “Are we being penny-wise and pound-foolish?” Logging has been a highly political debate since Theodore Roosevelt’s conservationist initiatives, but as with most political debates, regulation swings from one end of the political pendulum to the other depending on which party has majority power and/or the loudest pulpit. Volleying from one extreme resolution to another sets up a situation in the environment for which nature must try to compensate by succumbing to its own seemingly extreme response such as large wildfires and massive pine beetle outbreaks in order to regain a natural balance.

Economic incentives have always fostered a mobilization of problem solving and the overall lack of economic incentives coupled with the lack of logging and wood processing infrastructure in Colorado has meant that much of the pine beetle devastation remained a waste instead of becoming an opportunity. There are still plenty of forests that need to be mitigated; therefore generous tax incentives to both consumers and corporations, and a moderation of political agendas could successfully stimulate the economy and address the pine beetle infestation issue.


3 Ibid.


11 Ibid.


13 Ibid.

14 As a Rocky Mountain regional example, by 1907, an 881,841 acre region (1,378 square miles) in southern New Mexico was home to 17,000 cows and horses, 10,000 sheep, and 40,000 goats. Colorado, no doubt experienced similar industry trends.


18 Ibid.

19 According to the county’s products information guide, carbaryl has a half life in sandy loam soils of 7-14 days, a half-life in clay soils of 14-28 days, and a half-life in water is about 10 days with non-acid, neutral pH conditions.
Extension Toxicology Network (extoxnet archived and maintained by Oregon State University)  

20 Ibid.
21 Ibid.

22 Bradbury, S. in Amended registration eligibility decision (RED) for Carbaryl, EPA-738-R-08-010 (United States Environmental Protection Agency, Office of Prevention, Pesticides and Toxic Substances, August 2008, revised).

23 For example, a later statement from the EPA dated in 2010 revises the application process for carbaryl around marine habit which hosts Pacific salmon and steelhead fish in California, Oregon, Washington, and Idaho. The application process is restricted in six different ways, including being subject to wind speed restrictions during the application process and localized monitor measurements to be conducted and paid for by the person responsible for the application of the pesticide. Therefore, serious health and safety concerns do surround use of the pesticide on MPB regardless of its potential effectiveness on MPB and subsequent effects on human health such as insecticide residues penetrating water sources.

United States Environmental Protection Agency, Office of Chemical Safety and Pollution Prevention  


28 Ibid.
29 Ibid.


Hallman, H. & Piehl, B. *A spatial model to determine the economic availability of woody biomass in Colorado.* Presentation (The Greenslends Reserve, June 2009).


Altson, Diane G. *Insects that kill trees.* Professional Tree Care Workshops (Utah State University, 2004).


Altson, Diane G. *Insects that kill trees.* Professional Tree Care Workshops (Utah State University, 2004).


Ibid.


Ibid.


*Colorado Sales/Use Tax Rate.* Publication DR 1002 (Colorado Department of Revenue, Denver, Colorado July 2011).


Ibid.