Mountain Pine Beetles and Forest Destruction: Effects, Responses, and Relationship to Climate Change

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Summary

The mountain pine beetle is a native insect of western U.S. pine forests. It survives by killing infested trees, usually individually, but occasionally in epidemics. Mountain pine beetle epidemics are particularly associated with lodgepole pine, a common western tree that typically grows in dense, even-aged stands. The beetle is a seasonally adapted species that thrives in areas where it can complete its life cycle in one year. The beetle has evolved a mass-attack approach to overwhelm tree defenses through large numbers, and adults congregate on large trees under stress. Widespread stress (e.g., a regional drought) sets the stage for an epidemic.

Mountain pine beetle epidemics are recurrent events in western forests. The current epidemic can be separated into three distinct events: the central U.S. Rocky Mountains, interior British Columbia (Canada), and high-elevation pines. Two aspects of the current epidemic are widely believed to have been exacerbated by climate change: (1) increased temperatures farther north and at higher elevations (allowing complete life cycles in areas previously not susceptible to the beetle) and (2) possibly regional drought (making trees more susceptible to beetle attacks).

Controlling a mountain pine beetle epidemic can be problematic. Individual trees can be protected by insecticide sprays, but the cost of preventive spraying at a landscape scale is prohibitive. Once a tree is infested, nothing can be done to save the tree. In the long run, silvicultural treatments to provide less dense, more diverse forests may reduce the extent of future epidemics, but epidemics cannot be prevented.

One concern about the consequences of the current epidemic is the possible increase in wildfire threats. Little research has been done to assess the change in threats and impacts of wildfires. The limited existing information suggests that tree mortality due to mountain pine beetles may have little effect on the threat or impacts of wildfire in the affected areas, because lodgepole pines (live or dead) naturally burn in extensive crown fires that typically kill most of the large trees. Furthermore, because of the natural regeneration cycle of lodgepole pine and because the beetles do not kill small trees, natural regeneration of the pine forests is likely.

However, warming as a result of climate change could have two consequential ecological outcomes. First, the beetle outbreak in the high-elevation pine ecosystems could significantly alter these ecosystems, because these pines are much slower to regenerate and small high-elevation pines are highly susceptible to the white pine blister rust (an introduced fungus). The second concern is the potential for the mountain pine beetle to spread across northern Canada through the boreal jack pine forest, and become an invasive pest of eastern pine forests.

There are economic consequences of the mountain pine beetle epidemic. The aesthetic values of the area—such as property values and tourism—will likely be harmed by the extensive tree mortality. Much of the beetle-killed timber could be used, for lumber or for biomass energy, but the substantial volume of timber available far exceeds existing capacity to use the wood, and expanding capacity could be unsustainable—a short-run surplus and long-run shortage. Also, Canadian lumber faces restrictions on shipments to U.S. markets.

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Numerous insect epidemics appear to be damaging North American forests at unprecedented levels. Many fear that the dying trees will further increase wildfire threats, alter ecosystems, and disrupt wood supplies for current and future housing and other uses. In the past, Congress has created special research or control programs for insect epidemics. The continuing concern over wildfires and forest health may lead to congressional efforts to combat the epidemics. Some also assert that insect epidemics are exacerbated by global climate change, and that they may even contribute to that change. This report examines the mountain pine beetle (*Dendroctonus ponderosae*) epidemic because it is one of the most damaging insects affecting forests and because more is known about its life cycle than the cycles of many other forest pests.

The Mountain Pine Beetle

The mountain pine beetle is one of a number of bark beetles native to the western forests of North America, several of which are currently infested at epidemic levels. Mountain pine beetles inhabit most species of western pine, including ponderosa pine, white pine, sugar pine, limber pine, and whitebark pine, but epidemics are particularly associated with lodgepole pine. Lodgepole pine is a common tree from the Colorado Rockies and Sierra Nevada north to the Yukon Territory. It typically grows in dense, even-aged stands that have regenerated following intense wildfires that killed the previous stand.[1]

Life Cycle of the Mountain Pine Beetle

The mountain pine beetle is a seasonally adapted insect, successfully reproducing and occasionally reaching epidemic levels where it is *univoltine*—completing an entire life cycle in one year.[2] The majority of its life is spent as larva in the *phloem* (innermost bark layer) of pine trees. The eggs hatch 10-14 days after being laid, and the larvae feed on the phloem. In the fall, the larvae produce *glycerol*, a natural antifreeze that allows them to survive winter temperatures.[3] Larvae are vulnerable to frosts in the fall, before producing glycerol, and when they pupate. During winter, temperatures below -30°F for at least five days can kill most larvae.[4] Larvae pupate in very late spring or early summer (usually June).

Adult mountain pine beetles usually emerge in midsummer, late enough to avoid harm from late spring frosts but early enough to allow eggs to hatch into larvae; ambient air temperatures determine the timing of emergence.[5] The adults disperse, with preference for trees of larger

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[1] Most lodgepole pines are *serotinous* through much of the species' range. The cones are highly resinous and tightly closed, and do not release the seeds until heated sufficiently to melt the resin—113°-140°F. (See James E. Lotan and William B. Critchfield, "*Pinus contorta*: Lodgepole Pine," *Silvics of North America, Vol 1. Conifers*, USDA Forest Service, Agriculture Handbook 654, Dec. 1990, p. 305.) Thus, a new lodgepole pine forest is regenerated when an intense wildfire kills the trees and opens the cones to spread the seeds, as occurred on an extensive scale in 1988 in Yellowstone National Park.

[2] Jesse A. Logan and James A. Powell, "Ghost Forests, Global Warming, and the Mountain Pine Beetle (Coleoptera: Scolytidae)," *American Entomologist*, vol. 47, no. 3 (fall 2001), pp. 160-173.

[3] D. A. Leatherman, I. Aguayo, and T. M. Mehall, *Mountain Pine Beetle*, Colorado State Univ. Extension, no. 5.528, at http://www.colostate.edu/pubs/insect/05528.html.

[4] Leatherman et al., *Mountain Pine Beetle*.

[5] Les Safranyik, "Mountain Pine Beetle: Biology Overview," *Proceedings—Symposium on the Management of* (continued...)

diameter (thicker trees have thicker phloem, and thus more food) and trees under stress (e.g., injured, diseased, or suffering from drought, and thus offering less resistance to attack). Trees less than five inches in diameter are rarely attacked, even in an epidemic.[6] Females first attacking a tree release chemicals called *aggregating pheromones*, which attract males and other females in a mass attack on the tree.[7]

The beetles cannot readily attack and kill any tree. Native predators, notably woodpeckers and clerid beetles, help to control populations.[8] In addition, the trees "have evolved significant defensive chemistry that serves to protect them from beetle attack. The mountain pine beetle, in turn, has evolved a mass-attack strategy that overwhelms tree defenses through sheer numbers of attacking beetles."[9] Also, the beetles introduce a blue-stain fungus into the trees they attack, which clogs water transport systems and contributes to killing the trees. [10] Thus, trees under stress—from drought, disease, injury, or other cause—are more susceptible to attack by the mountain pine beetle and blue-stain fungus. When a widespread stress (e.g., a regional drought) affects a forest with many relatively large-diameter lodgepole pine trees, the stage is set for a mountain pine beetle epidemic.

Mountain Pine Beetle Epidemics

Mountain pine beetle epidemics have occurred in lodgepole pine forests for thousands of years. Epidemics lasting 5 to 20 years occur at irregular intervals, affecting large areas and often killing more than 80% of the trees of more than 10 centimeters (about 4 inches) in diameter.[11] There is wide variability in the mortality of pure lodgepole pine forests, and even forests that appear to be completely killed will have lodgepole pine seedlings and saplings released from the competition in dense stands.[12]

There is no single, simple cause for a population to reach epidemic levels. Research has provided information about the population ecology of the mountain pine beetle in lodgepole pine, but not about the transition to epidemic populations.[13] Widespread stress in a mature forest clearly provides a setting for an outbreak, but no specific trigger has been identified. One source suggests that prolonged warm periods, especially with warm winters, may trigger epidemics, [14] but the

(...continued)

Lodgepole Pine to Minimize Losses to the Mountain Pine Beetle (Kalispell, MT, July 12-14, 1988), USDA Forest Service, Intermountain Research Station, Gen. Tech. Rept. INT-262 and SAF 89-03, Ogden, UT, May 1989, pp. 9-13.

[6] "Bark Beetles: Mountain Pine Beetle," at http://www.fs.fed.us/r1-r4/spf/fhp/field_guide/PDFs/MountainPineBeetle58.pdf.

[7] Gene D. Amman, Mark D. McGregor, and Robert E. Dolph, Jr., *Mountain Pine Beetle*, USDA Forest Service, Forest Insect & Disease Leaflet 2, reprinted 1990.

[8] Leatherman et al., *Mountain Pine Beetle*.

[9] Logan and Powell, "Ghost Forests," p. 162 (citations omitted).

[10] "Bark Beetles: Mountain Pine Beetle."

[11] Safranyik, "Mountain Pine Beetle: Biology Overview," p. 9.

[12] Merrill R. Kaufmann et al., *The Status of Our Scientific Understanding of Lodgepole Pine and Mountain Pine Beetle—A Focus on Forest Ecology and Fire Behavior*, The Nature Conservancy, GFI Tech. Rept. 2008-2, Arlington, VA, 2008.

[13] Safranyik, "Mountain Pine Beetle: Biology Overview," p. 11.

[14] Kaufmann et al., *Lodgepole Pine and Mountain Pine Beetles.*

evidence is not conclusive. During epidemics, natural controls (e.g., woodpeckers and clerid beetles) have little effect on mountain pine beetle population levels.[15]

The Current Mountain Pine Beetle Epidemics

The current mountain pine beetle epidemic is actually three geographically or ecologically distinct epidemics, with quite different situations and consequences. One is in the lodgepole pine stands of the central Rocky Mountains—primarily in Colorado and Wyoming. Another is in the lodgepole pine stands of central British Columbia. The third is in high-elevation pines, primarily in Wyoming, Montana, and Idaho.

The Lodgepole Pine Epidemic in the Central Rocky Mountains

The current mountain pine beetle epidemic in Colorado and Wyoming is extensive, but it is unclear whether the current level is unprecedented. Most researchers note that mountain pine beetle epidemics are known to have occurred in lodgepole pine forests, but that the current epidemic is more extensive than has been seen in the past century. However, one source noted the loss of 15 billion board feet of lodgepole pine timber from mountain pine beetles in Idaho and Montana from 1911 to 1935.[16] Although the current epidemic is extensive, it may be normal and natural.[17] Some researchers have stated:

> Even though insect outbreaks greatly affect forest ecosystems, they may not be detrimental from a long-term ecological perspective. Such disturbances may in fact be crucial to maintaining ecosystem integrity, a situation ... described as "normative outbreaks." [18]

The current epidemic is extensive, largely because vast areas of lodgepole pine provide suitable habitat for the mountain pine beetle.[19] This expanse of mature lodgepole pine forests in the central Rocky Mountains is the result of natural but widespread severe wildfires in the 19th century.[20] Thus, while the current epidemic is unsightly and may have significant consequences (as discussed below), it is an extreme version of an undesirable but normal, natural event.

The epidemic may have been exacerbated by climate change. Climate change may have altered precipitation patterns, contributing to the current extended drought in the Rocky Mountain region. This drought has put stress on the trees, leaving them vulnerable to attack by insects and diseases, including the mountain pine beetle. Thus, climate change may be a contributing factor in the mountain pine beetle outbreak in the lodgepole pine ecosystems of the central Rockies.

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[15] Leatherman et al., *Mountain Pine Beetle*; Safranyik, "Mountain Pine Beetle: Biology Overview."

[16] "Mountain Pine Beetle Biological Control," *Bark and Wood Boring Beetles of the World*, at http://www.barkbeetles.org/Biocontrol/mountainpinebeetle.html.

[17] W. H. Romme et al., *Recent Forest Insect Outbreaks and Fire Risk in Colorado Forests: A Brief Synthesis of Relevant Research*, Colorado Forest Restoration Institute, Colorado State Univ., Colorado State Forest Service, and Univ. of Idaho, 24 pp.

[18] Jesse A. Logan, Jacques Règniére, and James A. Powell, "Assessing the Impacts of Global Warming on Forest Pest Dynamics," *Frontiers in Ecology and the Environment*, vol. 1, no. 3 (2003): p. 130.

[19] Kaufmann et al., *Lodgepole Pine and Mountain Pine Beetles.*

[20] Romme et al., *Recent Forest Insect Outbreaks and Fire Risk in Colorado Forests*.

The Lodgepole Pine Epidemic in Canada

The interior forests of British Columbia (BC), stretching west from the Rocky Mountain crest to the east side of the Coast Range, are similar to U.S. forests of the Rocky Mountains, and include extensive stretches of mature lodgepole pine. As with the lodgepole pine forests of the central U.S. Rockies, the mountain pine beetle is an endemic (native) species, with periodic epidemics. However, the current epidemic is the most severe ever recorded, and is expected to kill up to 80% of the mature lodgepole pine in BC within the next decade.[21]

The current mountain pine beetle infestation has reached farther north and east than previous epidemics. This is likely the result of climate change leading to insufficient freezing temperatures farther north than previously recorded. Thus, the mountain pine beetle can become univoltine (completing its life cycle in one year) farther north than previously recorded. While the mountain pine beetle outbreak in central and southern BC may be within historic norms, as in the central U.S. Rockies, the epidemic is likely to reach farther north than its historically normal distribution because of climate change.

The Epidemic in High-Elevation Pines

Mountain pine beetles are also endemic to whitebark, bristlecone, and other high-elevation pines. These trees inhabit upper mountain slopes (together with spruce and subalpine fir), and at the extreme grow in the *krummholz* form (German for *twisted wood*)—the classic stunted, wind-swept pines of timberline. Whitebark pine forests have generally been "climatically unsuited for outbreak populations of the mountain pine beetle."[22] The high elevations have typically led to short summers (preventing univoltine populations) and to cold winters (which kill mountain pine beetles). However, a beetle epidemic in whitebark pine in central Idaho in the 1930s coincided with a series of unusually warm years.[23] The dead trees are still standing, a stark reminder that not all forests are adapted to recover from devastating natural events. As with the mountain pine beetle outbreak in extreme northern BC, climate change is likely a significant factor in the current epidemic in high-elevation pine ecosystems, because warmer temperatures allow the mountain pine beetle to become univoltine in these areas.

While insignificant for timber, the whitebark pine is a critical element in the northern U.S. Rocky Mountain ecosystems, because it produces an abundance of the large, high-protein seeds that are important mainstays for several animal species, particularly grizzly bears. The loss of whitebark pine, a key food in the fall prior to hibernation, could devastate bear populations by lowering reproductive success and forcing grizzlies to forage at lower elevations where there would be more human conflicts.[24] These forests and animals are American symbols of wilderness and endangered species, and their decline might harm these values.

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[21] Natural Resources Canada, *Responding to the Mountain Pine Beetle Infestation*, Sept. 24, 2007, at http://canadaforests.nrcan.gc.ca/articletopic/138?format=print.

[22] Jesse A. Logan, "Climate Change Induced Invasions by Native and Exotic Pests," *Proceedings, 17th U.S. Department of Agriculture Interagency Research Forum on Gypsy Moth and Other Invasive Species*, USDA Forest Service, Northern Research Station, Gen. Tech. Rept. NRS-P-10, Newton Square, PA, 2006, p. 9.

[23] Logan and Powell, "Ghost Forests," pp. 168-170.

[24] David J. Mattson, Katherine C. Kendall, and Daniel P. Reinhart, "Whitebark Pine, Grizzly Bears, and Red Squirrels," *Whitebark Pine Communities: Ecology and Restoration*, Island Press, Washington, DC, 2001, pp. 124-130.

Controlling Mountain Pine Beetle Epidemics

Short-Term Control

Little, if anything, can be done to halt or disrupt a mountain pine beetle epidemic. Because the beetles live under the bark, it is difficult to kill them with insecticides; getting the insecticide to the beetles involves injecting every infected tree—millions of trees over thousands of acres. As one group of researchers noted, "once MPB [the mountain pine beetle] infests a tree nothing practical can be done to save that tree."[25]

Preventing the mountain pine beetle from spreading to uninfested trees is also virtually impossible. Individually valuable trees, such as those near residences or in campgrounds, can be protected by insecticide sprays, but the cost is prohibitive at a landscape scale.[26] Silvicultural treatments (timber harvests and other tree stand management practices) are sometimes discussed as a way to restrict the spread of the mountain pine beetle,[27] but some observers have noted that such efforts are unlikely to make a difference, at least in the short run:

> In the current epidemic, it is impractical to expect that silvicultural treatment of lodgepole pine forests will prevent or even impede the advance of the epidemic in Colorado and southern Wyoming. There are simply too many suitable host trees over too large an area, and unusually high insect populations. [28]

Silvicultural treatments are unlikely to have a short-term effect on mountain pine beetle epidemics for two reasons. First, "the direction and spread rate of a beetle infestation is impossible to predict."[29] Even though prevailing winds and warming temperatures provide general directionality, epidemics spread in a random fashion. Second, even though infestations usually spread only to neighboring trees, mountain pine beetles can travel long distances to infest trees—up to 200 kilometers (125 miles).[30]

Long-Term Control

Researchers have suggested that active forest management could reduce the likelihood of future epidemics and the severity of the consequences when epidemics occur. [31] Forest practices can provide diverse forest landscapes, with patches varying in tree age and size, and with more species diversity where feasible. Possible activities include reducing stand densities, removing unhealthy or stressed trees, and creating openings to regenerate seedlings. However, these

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[25] Leatherman et al., *Mountain Pine Beetle*, p. 3.

[26] Kaufmann et al., *Lodgepole Pine and Mountain Pine Beetles*; Romme et al., *Recent Forest Insect Outbreaks and Fire Risk in Colorado Forests*.

[27] See, for example, Gene D. Amman, compiler, *Proceedings—Symposium on the Management of Lodgepole Pine to Minimize Losses to the Mountain Pine Beetle* (Kalispell, MT, July 12-14, 1988), USDA Forest Service, Intermountain Research Station, Gen. Tech. Rept. INT-262 and SAF 89-03, Ogden, UT, May 1989, 119 pp.

[28] Kaufmann et al., *Lodgepole Pine and Mountain Pine Beetles*, p. 9.

[29] Leatherman et al., *Mountain Pine Beetle*, p. 3.

[30] "Winter Offensive Planned to Burn Out Pine Beetles in Central Alberta," *Canadian Press* (Oct. 23, 2008).

[31] Kaufmann et al., *Lodgepole Pine and Mountain Pine Beetles*; Romme et al., *Recent Forest Insect Outbreaks and Fire Risk in Colorado Forests*.

activities can be expensive, even in places where a commercial timber industry exists to harvest and utilize the wood.[32] Others caution that some activities, such as conventional timber harvests and salvage harvests, may have little effect on the future stand conditions. This type of harvesting might not reduce the potential for catastrophic wildfires or insect epidemics.[33] A group of authors noted:

> Creating diverse patch ages and sizes (including young patches) and perhaps more mixed-species forests across the landscape may or may not reduce the spread of future mountain pine beetle outbreaks, but it likely would reduce the amount of forest susceptible through time to a monolithic [uniform, widespread] disturbance, including mountain pine beetle attack or fire. Thus while unproven, the increased landscape heterogeneity may be effective for limiting the scale and severity of future mountain pine beetle impacts. The effectiveness of such measures cannot be assured, nor are all the ecological consequences known, though even in the current epidemic, stands and patches of younger lodgepole pine trees appear to have survived the epidemic with no or only limited mortality. [34]

Creating a more diverse, less dense, less stressed forest landscape will not prevent all future mountain pine beetle epidemics. Other factors, such as temperature and precipitation, are also important in determining when and where outbreaks will occur. Researchers caution that eradicating mountain pine beetles is probably infeasible, and would be undesirable—they are a native species with important ecological roles, whose loss could harm natural ecological systems in unexpected ways.[35]

Consequences of Mountain Pine Beetle Epidemics

The current mountain pine beetle epidemics may have various ecological and economic consequences. The impacts depend on several factors, such as the ecosystem affected and the socioeconomic responses to the epidemic.

Ecological Consequences

The mountain pine beetle epidemic has two primary impacts of concern: first, the possible increase in wildfire threat, and second, forest regeneration following the epidemic. The effects on lodgepole pines in the American Rockies and British Columbia are similar, and thus are discussed together. The effects on the high-elevation pines are different, and are discussed separately. In addition to these two primary concerns, trees killed by the mountain pine beetle will eventually release their carbon to the forest soils or to the atmosphere, either quickly through wildfires or more slowly through decay. Other than new forest stands to sequester carbon and long-term wood products to store some of the carbon from beetle-killed trees, little can be done to ameliorate the carbon release. Thus, mountain pine beetles release forest carbon to the atmosphere, creating a

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[32] See CRS Report RL32485, *Below-Cost Timber Sales: An Overview*, by (name redacted), and CRS Report RS20985, *Stewardship Contracting for Federal Forests*, by (name redacted).

[33] Romme et al., *Recent Forest Insect Outbreaks and Fire Risk in Colorado Forests.*

[34] Kaufmann et al., *Lodgepole Pine and Mountain Pine Beetles*, pp. 9-10.

[35] Safiya Samman and Jesse Logan, *Assessment and Response to Bark Beetle Outbreaks in the Rocky Mountain Area*, USDA Forest Service, Intermountain Research Station, Gen. Tech. Rept. RMRS-GTR-62, Ogden, UT, September 2000, p. iv.

"positive feedback loop"—forest carbon release aggravates climate change, leading to further mountain pine beetle epidemics.[36]

Ecological Effects on Lodgepole Pine Ecosystems

The initial concern about the ecological impacts of mountain pine beetles on lodgepole pines is the apparent increase in the threat of wildfire conflagrations from the large numbers of dead and dying trees. Two groups of researchers have examined this concern and found little evidence to support or refute the belief that extensive mountain pine beetle epidemics increase the threat of conflagrations.[37] Thus, both groups chose to examine the impacts by assessing likely changes in wildfire behavior over time in lodgepole pine stands killed by mountain pine beetles.

Both groups of researchers noted that wildfire is a complex phenomenon, with fire intensity depending on variations in weather (wind and fuel moisture content) as well as the level and the arrangement of fuels. Lodgepole pine forests historically burned occasionally, typically in crown fires (conflagrations that kill most of the trees in the stand) under extreme weather conditions. Both research groups concluded that the threat of a conflagration remains high while the dead needles remain on the trees—up to two years following the infestation. After the needles fall, the threat of a conflagration declines, because the forests lack the small-diameter fuels needed to start and spread the fire. After the dead trees fall—one to several decades after the outbreak—the risk increases for intense surface fires. However, both research groups also noted that even intense surface fires would be within the historic range of natural variability of lodgepole pine ecosystems, and not something unusual or catastrophic for lodgepole pine ecosystems. One of the groups did caution, however, that the magnitude and extent of the current mountain pine beetle outbreak has not been experienced since white settlers reached the Rocky Mountains, and thus:

> we are uncertain about fire behavior at landscape or regional scales because we have not seen systems with such heavy fuel loads over such extensive areas; and we know little about the ecological consequences of such fires at these scales.[38]

The other ecological concern is about the regeneration of lodgepole pine forests following the mountain pine beetle epidemic. Areas dominated by relatively small trees (less than 5 inches in diameter) are likely to remain green lodgepole pine forests, since trees of this size are rarely attacked. Areas with extensive beetle-killed trees will likely regenerate to lodgepole pine forests, but it may take time, since wildfire is needed to open the serotinous cones of the remaining live lodgepole pine trees. However, once such a fire occurs, vast areas can be reforested, since lodgepole pine is a prolific seed producer. As one group of researchers noted:

> Is re-establishment of lodgepole pine assured after the mountain pine beetle epidemic? Undoubtedly, but subtle or even large shifts in its location and plant associations are not out of the question.[39]

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[36] For a discussion of forests and the carbon cycle, see CRS Report RL31432, *Carbon Sequestration in Forests*, by (name redacted). For a discussion of positive feedbacks in climate, see CRS Report RL33849, *Climate Change: Science and Policy Implications*, by (name redacted).

[37] Kaufmann et al., *Lodgepole Pine and Mountain Pine Beetles*; Romme et al., *Recent Forest Insect Outbreaks and Fire Risk in Colorado Forests*.

[38] Kaufmann, et al., *Lodgepole Pine and Mountain Pine Beetles*, p. 13.

[39] Kaufmann et al., *Lodgepole Pine and Mountain Pine Beetles*, p. 17.

Others are more sanguine, suggesting that lodgepole pine trees killed by mountain pine beetles are important contributors to the stand-replacement fires that favor lodgepole regeneration.[40]

Ecological Effects on High-Elevation Pine Ecosystems

Concerns about the effects of the mountain pine beetle outbreak on high-elevation pine ecosystems are the same as for lodgepole pine ecosystems—wildfire threats and forest regeneration—but the effects are different. As in lodgepole pine ecosystems, the wildfire threat is largely unchanged by tree mortality due to mountain pine beetles. Wildfires are still likely to be of mixed intensity, with some crown fires, especially in areas with spruce and fir (which are not affected by the mountain pine beetle) mixed with the high-elevation pines.

The mountain pine beetle epidemic combined with other problems might prevent successful regeneration of these pine stands. The interspersed pattern of openings created by crown fires, together with the destruction of spruce and fir by wildfire, creates opportunities for whitebark pine and other high-elevation pines (such as bristlecone and foxtail pines) to regenerate. However, mountain pine beetles typically kill the largest-diameter trees—those that produce most of the seeds needed for regeneration. In addition, the high-elevation pines are susceptible to destruction by white pine blister rust. This introduced fungus slowly kills infected five-needle pines (including the high-elevation pines), especially seedlings and saplings. [41] With the mountain pine beetle killing seed source trees and white pine blister rust killing regeneration, the future of high-elevation pine ecosystems is uncertain. Thus, climate change that is allowing univoltine outbreaks of mountain pine beetle in the high-elevation pines might eliminate the pines from high-elevation areas.

Ecological Effects on Other Ecosystems

One additional ecological concern relates exclusively to the mountain pine beetle outbreak in British Columbia. As noted above, the current epidemic has reached farther north and east than any previous epidemic. **Figure 1** shows the historic distribution of the beetles reaching the eastern border of BC, about 150 miles from the forested area in central Alberta where lodgepole pine mixes with the jack pine forest that stretches east to the Atlantic Ocean. An outbreak has been reported in Alberta within 30 miles of the overlap.[42]

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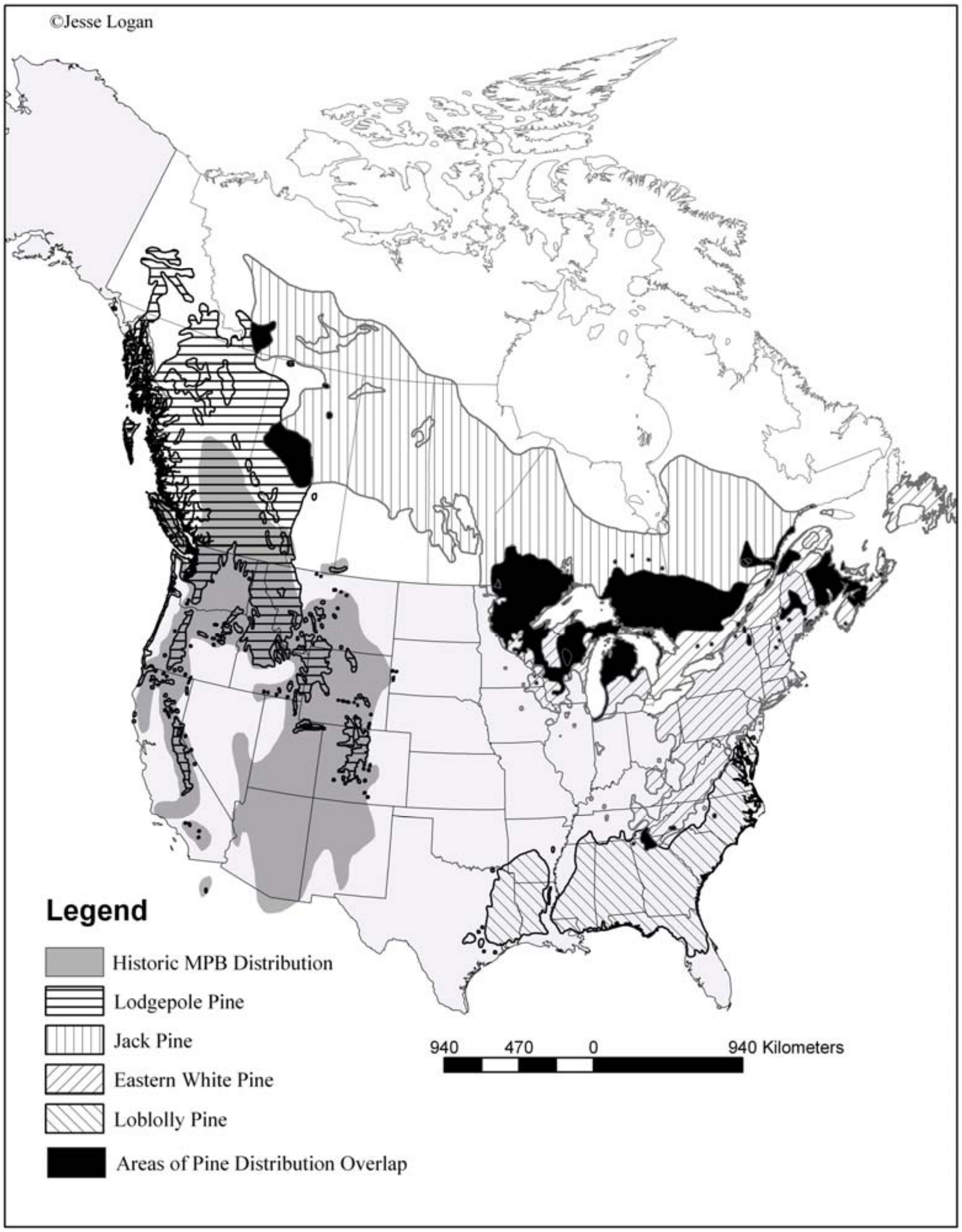
[40] Logan and Powell, "Ghost Forests."

[41] Jonathan P. Smith and James T. Hoffman, "Status of White Pine Blister Rust in the Intermountain West," *Western North American Naturalist*, vol. 60, no. 2 (2000), pp. 165-179.

[42] Jesse A. Logan and James A. Powell, "Ecological Consequences of Climate Change Altered Forest Insect Disturbance Regimes," *Climate Change in Western North America: Evidence and Environmental Effects* (Univ. of Utah Press, in press), p. 15.

Figure 1. Mountain Pine Beetle (MPB) Distribution Map



Source: Jesse A. Logan and James A. Powell, "Ecological Consequences of Climate Change Altered Forest Insect Disturbance Regimes," *Climate Change in Western North America: Evidence and Environmental Effects* , Univ. of Utah Press, Salt Lake City, UT, in press.

If the mountain pine beetle infests jack pine, it could lead to a rapid and devastating eastward spread across Canada and southward into the United States, because jack pine has not evolved the defenses against the mountain pine beetle that lodgepole pine has developed.[43] "What we are describing, here, is a potential biogeographic event of continental scale with unknown, but potentially devastating, ecological consequences implied by an invasive, native species."[44] Furthermore, if the mountain pine beetle spreads to the Great Lakes and farther east, the beetle could infest other pine species, such as eastern white pine, and even move south to infest the southern yellow pines. **Figure 1** also shows the distribution of these various pine species, and thus the potential spread of the mountain pine beetle. The potential consequences are enormous, and the potential to prevent the spread is extremely limited, as discussed above.

Economic Consequences

There are several economic consequences of the extensive mountain pine beetle infestation. The most obvious economic impacts are on aesthetic values, from the expanses of dead trees, and on wood supplies. In addition, climate-change-induced or -exacerbated mountain pine beetle outbreaks can have additional effects, such as altering the timing and quality of water runoff in affected forests.

Aesthetics

Expanses of dead trees clearly hurt aesthetic values. People have built homes in these areas because they want to live in the forest. While the forests will eventually recover, as discussed above, many do not want to wait several years to decades for that recovery. These people will also face financial losses if they try to sell their homes in the woods, since others are less likely to want to buy a house surrounded by dead trees. Thus, home prices in areas with mountain pine beetle outbreaks will likely be depressed, probably for years. Also, homeowners and potential home buyers fear that the expanses of dead trees increase the vulnerability of the homes to wildfires. As noted above and discussed further elsewhere,[45] however, expanses of dead lodgepole pine may pose little additional threat to structures, particularly if homeowners act to protect their homes. Nonetheless, home protection from wildfires might entail additional costs for homeowners.

Another aesthetic effect of expanses of dead trees is the impact on tourism. In many areas of the intermountain West, beautiful scenery is a major attraction. Hillsides full of dead trees are likely to dissuade people from spending time, and money, in areas affected by mountain pine beetle outbreaks. Evidence from the wildfires in Yellowstone in 1988 clearly shows that tourism is hurt by vistas filled with dead trees.[46]

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[43] However, jack pine, like lodgepole, mostly has serotinous cones opened by fire, and therefore is similarly adapted to regenerate new stands following conflagrations.

[44] Logan and Powell, "Ecological Consequences of Climate Change."

[45] For information on protecting homes from wildfire threats, see CRS Report RL34517, *Wildfire Damages to Homes and Resources: Understanding Causes and Reducing Losses*, by (name redacted).

[46] Paul E. Polzin, Michael S. Yuan, and Ervin G. Schuster, *Some Economic Impacts of the 1988 Fires in the Yellowstone Area*, USDA Forest Service, Intermountain Research Station, Research Note INT-418, Ogden, UT, October 1993.

Wood Utilization

Direct economic consequences of the mountain pine beetle epidemics relate to the enormous quantity of dead wood available in the short run, and the dearth of wood supplies in the period between the end of useful salvage operations and the maturing of the regenerated forest. While there is no threat of spreading the beetles in the wood products or energy produced, it is unclear whether transporting the unprocessed logs might exacerbate the beetle's spread. There are three primary opportunities for using trees killed by the mountain pine beetle—lumber, paper, and biomass energy.

Lumber Production

Beetle-killed trees can be used to produce lumber for at least five years after they die, and up to 18 years, depending on circumstances.[47] The blue-stain fungus in beetle-killed trees alters the appearance of the wood products but has no effect on wood product strength or adhesion properties.[48] Thus, wood products from beetle-killed trees are perfectly acceptable in virtually all traditional wood uses, such as residential construction and shipping containers.

Since trees contain substantial quantities of carbon, their death and subsequent deterioration (through wildfires or decay) releases much of that carbon back to the atmosphere. Converting the dead wood into lumber for long-term uses, such as housing, can mitigate the carbon impacts of the dying trees. Through storage in wood products, it may be possible to ameliorate the impacts of the mountain pine beetle on climate change.

There are limitations to converting beetle-killed trees into lumber. One problem is lack of lumber production capacity. Lumber production levels in interior western states have fallen substantially in the past 15 years.[49] Lumber output has fallen so much in Colorado, Utah, and Wyoming that production in these states is no longer reported separately; 2007 lumber production in Montana and the Four Corners states was about half of 1992 production. Since trees are bulky, low-value commodities, shipping them more than about 100 miles for processing is economically impractical. With the decline in production, there might be insufficient capacity to convert more than a small portion of the beetle-killed lodgepole pine into lumber.

A limitation for the high-elevation pines is the lack of market value, as well as distance from processing facilities and sometimes even from roads. Whitebark, bristlecone, and other high-elevation pines generally grow in relatively short, twisted forms that cannot be readily milled into lumber. Thus, this is not an option for these mountain pine beetle-killed trees.

Canadian timber faces an additional limitation. It is unclear whether lumber production capacity is a constraint on using beetle-killed trees in Canada. However, lumber markets could be a problem. The largest market for Canadian lumber is the U.S. housing market. Even presuming that the current economic difficulties will be resolved quickly, and the U.S. housing market recovers from the doldrums, Canadian shipments to the U.S. market could continue to be constrained. In October 2006, the United States and Canada signed a Softwood Lumber

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[47] "Frequently Asked Questions," at http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/faq.htm.

[48] "Frequently Asked Questions," at http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/faq.htm.

[49] Western Wood Products Association, *Statistical Yearbook of the Western Lumber Industry*, Portland, OR, annual series, 1980-2007.

Agreement to settle pending litigation over U.S. efforts to restrain allegedly subsidized Canadian lumber. The seven-year agreement (with an optional two-year extension) establishes Canadian export charges, varying by weighted average lumber prices and lowered if the Canadian exporting region accepts specified volume constraints.[50] This agreement may limit the ability of Canadian companies to sell the lumber produced from beetle-killed trees.

Paper Production

As with lumber, it is feasible to produce paper from beetle-killed trees. The blue-stain fungus may require additional bleaching for some paper products. However, paper products generally do not provide the longer-term carbon storage afforded by lumber products. Thus, paper production offers little amelioration for the carbon release from beetle-killed trees. In addition, no *roundwood* (trees from the forest) in the West is used for paper production; all paper products in the region are made from sawmill wastes (log trimmings and sawdust) or plantations, typically of hybrid poplars, grown specifically for paper production.

Biomass Energy Production

Woody biomass can be used to produce energy in two primary manners—burning directly to produce heat or electricity, or to cogenerate both (also called combined heat and power, or CHP); and digesting to produce liquid fuel (e.g., ethanol) for transportation. Direct burning of wood for heat and energy has a very long history, and wood is still used as a primary home energy source in parts of the world (especially in the dry tropical forests of Africa). Modern use of CHP facilities has been expanding slowly. It is widely used by the wood products industry, utilizing waste wood, and its use in schools and government buildings continues to expand. A few free-standing energy facilities rely on wood. In contrast, transportation fuels from wood are still largely in the experimental or development stage. The technology exists, but commercial operations have yet to prove feasible.

There are some limitations to the potential use of beetle-killed timber for energy production. Currently, little capacity exists to use the substantial volume of dead wood to produce energy, either through direct burning or for transportation fuels, and what capacity does exist is not particularly near the available beetle-killed trees. Transporting the wood to existing facilities is impractical, since wood is a high-volume, low-value product with limited economic mobility. Capacity could be built, and the wood might still be available for many years, but some of the capacity to use the substantial volume would become superfluous after the available beetle-killed timber was all used. Either facilities would be idled or energy production would persist on possibly unsustainable wood harvests, damaging the forests in the long run.

[50] See CRS Report RL33752, *Softwood Lumber Imports from Canada: Issues and Events*, by (name redacted) and (name redacted).

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