DOES TREE-CUTTING TO ADDRESS BARK BEETLE INFESTATIONS REDUCE STAND SUSCEPTIBILITY TO OUTBREAKS?

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Adult pine beetles in egg gallery under bark.

TWO IMPORTANT QUESTIONS need to be considered when making forest management decisions in response to bark beetle outbreaks:

- Considering specific goals, what are the efficacies of various management strategies?
- What ecological and economic costs do these management strategies impose?

There is very little reliable empirical evidence to suggest that silvicultural treatments can effectively stop outbreaks once a large-scale insect infestation has started. Despite nearly 100 years of active forest management to control the mountain pine beetle, evidence for the efficacy of this approach is scant and contradictory (Wood *et al.,* 1985). Citing multiple sources, Hughes and Drever (2001) found that most control efforts have had little effect on the final size of outbreaks, although they may have slowed beetle progress in some cases and prolonged outbreaks in others. They also suggest that management interventions have never controlled a large-scale outbreak. Although control of such outbreaks is theoretically possible, it would require treatment of almost all of the infected trees (Hughes and Drever, 2001), which may be possible only for a small infestation.

In some situations, removing infested trees prior to the emergence of broods is recommended to protect remaining trees. However, the overall effectiveness of this strategy over a large area is unproved (Wilson and Celaya, 1998). Further, in most situations, it is probably not logistically feasible to locate and remove all trees before the emergence of adult beetles (Wilson and Celaya, 1998).

Amman and Logan (1998) point to failed attempts to use direct control measures, such as pesticides and logging, after an infestation starts. They suggest that by the early 1970s, it was apparent that controlling the extensive mountain pine beetle outbreaks that were occurring in the northern Rockies by directly killing the beetles was not working.

Wickman (1990) detailed the effort to control the mountain pine beetle at Crater Lake National Park in Oregon from 1925 to 1934. More than 48,000 trees were cut down and then burned in the last three years of the outbreak. The lesson learned was that once a mountain pine beetle population had erupted over a large area of susceptible forest, and as long as environmental conditions remained favorable, there was no effective way to stop the beetles until almost all the susceptible trees were either killed or removed by logging or until climatic conditions became unfavorable for sustaining an outbreak (Wickman, 1990).

The Crater Lake experience is not an isolated one, as control efforts have been standard practice across the West. Klein (1978) traced several mountain pine beetle epidemics from beginning to end and detailed the control efforts. More than 30,000 infested ponderosa pine trees and 20,000 infested lodgepole pine trees were treated in 1910 and 1911 in the Wallowa-Whitman National Forest in Oregon. The treatments included felling and peeling, felling and scoring the top, and felling and burning. Chemical methods were employed in the 1940s and '50s. DDT and other pesticides, such as lindane, were sprayed on thousands of acres across the intermountain West. In Operation Pushover, more than 1,800 acres of lodgepole pine in the Wasatch National Forest in Utah were mowed down by heavy tractors linked together, and the surrounding stands were sprayed with pesticides. In spite of these control attempts, mountain pine beetle outbreaks continued (Klein, 1978). Klein (1978) ultimately suggests that letting infestations run their course may be a viable option.

Pine beetle suppression projects often fail because the basic underlying causes (e.g., stand structure, age of trees, drought) of the outbreak have not changed (DeMars and Roettgering, 1982). Wood *et al.* (1985) point out that once bark beetles reach epidemic levels and cause extensive tree mortality, treatments aimed at stopping the outbreak are futile because it is logistically impossible to eliminate all suitable habitat or to mitigate the overriding effect of climate.

Large-scale efforts to control beetles are also expensive and ecologically harmful. The uncertain benefits of control efforts should be weighed carefully against costs (Hughes and Drever, 2001). In fact, much of the logging in stands infested with bark beetles has been to log merchantable timber. In 1994, then-U.S. Forest Service Chief Jack Ward Thomas, in testimony before the Senate Subcommittee on Agricultural Research, Conservation, Forestry and General Legislation, acknowledged that "the Forest Service logs in insect-infested stands not to protect the ecology of the area, but to remove trees before their timber commodity value is reduced by the insects." There is no doubt that timber extraction is a viable and legitimate use of national forest lands. However, it is important that ecosystem management be driven by clear and explicit goals (Christiansen *et al.,* 1996).

The Case for Thinning: Mixed Reviews

Because stressed and unhealthy trees may be more susceptible to bark beetles, another management approach is to modify stand structure by thinning forests before an outbreak starts. Some thinning studies show success in ameliorating mountain pine beetle infestations in lodgepole and ponderosa pine forests (Amman and Logan, 1998). But the overall evidence of the effectiveness of thinning is mixed.

The evidence for thinning

Most evidence supporting thinning as a control for bark beetles is based on tree vigor, not on directly measured insect activity in the stand. Thinning may increase tree vigor, which in turn may make trees less susceptible to insect infestation. The premise is that if the trees are healthy and highly vigorous, they may be able to "pitch out" the attacking beetles, essentially flooding the entrance site with resin that can push out or drown the beetle.

Some studies suggest that thinning forest stands to reduce competition for light and water may increase tree vigor, leaving what appear to be the best trees and resulting in less successful bark beetle attacks (Sartwell, 1971; Schmid and Mata, 2005; Fettig *et al.,* 2006). Larsson *et al.* (1983) examined the relationship between tree vigor and susceptibility to mountain pine beetle in ponderosa pine in central Oregon. Overall, low-vigor trees were more often attacked by beetles than high-vigor trees in early stages of outbreaks.

Perhaps the studies by Negrón most conclusively show that beetle activity is associated with high densities of stocking (Negrón, 1997; Negrón, 1998; Negrón *et al.,* 2000; Negrón *et al.,* 2001; Negrón and Popp, 2004). These studies show a positive correlation between attacked trees and poor growth. Research in Arizona, Utah and New Mexico showed roundheaded pine beetles (*Dendroctonus adjunctus*) prefer stands and trees exhibiting poor growth, and poor growth rates were positively correlated to dense stands (Negrón, 1997; Negrón *et al.,* 2000). Similarly, research in Colorado's Front Range showed Douglas-fir beetles attacked stands containing a high percentage of basal area represented by Douglas-fir, high tree densities and poor growth during the five years prior to attack (Negrón, 1998; Negrón *et al.,* 2001). Negrón and Popp (2004) reported that ponderosa pine plots in Colorado's Front Range infested by mountain pine beetle had significantly higher tree basal area and density.

Several studies in areas across the west have shown that thinning reduces the amount of mortality caused by mountain pine beetle in ponderosa pine stands (McCambridge and Stevens, 1982; Fiddler *et al.,* 1989, Schmid and Mata, 2005) and lodgepole pine (Cole *et al.,* 1983; Whitehead, 2005), and some scientists and managers recommend thinning as a viable management strategy for managing bark beetles in these forest ecosystems (Fettig *et al.*, 2007).

Evidence against thinning

Other research has found bark beetles do not preferentially infest trees with declining growth (Santoro *et al.,* 2001). Sánchez-Martínez and Wagner (2002) studied bark beetles in ponderosa pine forests of northern Arizona to see if differences in species assemblages and relative abundance were apparent for managed and unmanaged stands. They found no evidence to support the hypothesis that trees growing in dense stands are more colonized by bark beetles.

Some scientists have suggested caution in using thinning to control bark beetles because geographic and climatic variables may alter the effect (Hindmarch and Reid, 2001). Hindmarch and Reid (2001) found that pine engravers had longer egg galleries, more eggs per gallery and higher egg densities in thinned stands. Warmer temperatures in thinned stands also contributed to a higher reproduction rate (Hindmarch and Reid, 2001). However, pine engravers in Arizona had the opposite reaction to a similar thinning experiment (Villa-Castillo and Wagner, 1996).

There is also evidence to suggest that thinning can exacerbate pest problems. Outbreaks of pine engravers have been shown to be initiated by stand management activities such as thinning (Goyer *et al.,* 1998). The process of thinning can wound remaining trees and injure roots, providing entry points for pathogens and ultimately reducing the trees' resistance to other organisms (Paine and Baker, 1993). Hagle and Schmitz (1993) suggest that thinning can be effective in maintaining adequate growing space and resources to disrupt the spread of bark beetles; but note that there is accumulating evidence to suggest that physical injury, soil compaction and temporary stress due to changed environmental conditions caused by thinning may increase susceptibility of trees to bark beetles and pathogens.

Even if thinning does alleviate tree stress at the stand level it is unlikely to be effective against large-scale infestations (Safranyik and Carroll, 2006). Preisler and Mitchell (1993) used autologistic regression models to analyze mountain pine beetle colonization in thinned and unthinned lodgepole pine in Oregon. Thinned plots were initially reported to be unattractive to beetles; but when large numbers of attacks occurred, colonization rates were similar to those in unthinned plots (Preisler and Mitchell, 1993). Similarly, Amman *et al*. (1988) studied the effects of spacing and diameter of trees and concluded that tree mortality was reduced as basal area was lowered. However, if the stand was in the path of an ongoing mountain pine beetle epidemic, spacing and density of trees had little effect (Amman *et al.,* 1988).

Although thinning may be effective in certain circumstances, it must significantly reduce water stress to be effective, which is unlikely during severe droughts associated with many outbreaks. Thus, forest management, either in the form of searching for and removing infested trees or thinning forest stands before outbreaks, is unlikely to prevent major outbreaks due to the inherent difficulties of manipulating stand structure over large enough areas of Colorado and the overriding influence of climatic stress in driving outbreaks.

In conclusion, if a bark beetle infestation is relatively small and concentrated in a limited area, it may be feasible to reduce the population growth by removing infested trees from a forest stand or by thinning a stand to reduce stress on trees competing for limited nutrients, sunlight and moisture. For example, if a small stand of spruce is blown down by a windstorm and populations of bark beetles begin growing in fallen logs, then it may be feasible to remove all fallen, infested trees over a small area. However, given the climatic requirements for beetle population levels to reach epidemic levels, it is not known whether such a situation would lead to an outbreak. In other words, a small population of beetles is not sufficient for an outbreak to occur. Conversely, under climatic conditions favorable for an outbreak, such as those of the past decade, outbreaks of bark beetles can erupt simultaneously in numerous dispersed stands across the landscape. Unfortunately, even if a growing population of beetles is successfully removed from one stand, under outbreak conditions beetles from other stands are likely to spread over a landscape. Given that climate typically favors beetle populations and stresses trees over very large areas, it is unlikely that management could successfully identify and remove all populations of beetles over an extensive region. Thinning and associated roads can also have a negative impact on wildlife and water quality. Experimenting with thinning for bark beetle control should be done only on a limited scale in areas that are already roaded—not in ecologically sensitive roadless areas.

After the Fact: Post-Disturbance Logging After Outbreaks

Timber production may be an appropriate activity in the right places at the right times and with the right methods, and there may be economic benefits from utilizing some of the dead trees that are now abundant on the landscape, but from an ecological standpoint there is little or no need to remove trees killed by insects (Romme *et al.,* 2006), and tree removal may cause ecological harm and exacerbate insect outbreaks. Standing snags and fallen logs contribute to a number of ecological values in forests, including maintenance of natural forest structures and processes, protection of soils and water quality and preservation of species at risk from the effects of roads, exotic species and habitat alteration (Romme *et al.,* 2006).

Depending on how it is done, logging after a natural disturbance (so-called salvage or post-disturbance logging) can also inadvertently lead to heightened insect activity. Specifically, logging after insect outbreaks can reduce parasites and insect predators by effectively eliminating their habitat of standing and downed trees (Nebeker, 1989). Therefore, outbreaks could be prolonged because of a reduction in the effectiveness of the beetle's natural enemies (Nebeker, 1989). Standing dead trees are important for several birds that feed on mountain pine beetles (Steeger *et al.,* 1998), and the widespread removal of dead and dying trees eliminates the habitat required by insectivorous birds and other species with the result that outbreaks of pests may increase in size or frequency (Torgerson *et al.,* 1990). Post-disturbance logging differs from natural disturbance as it tends to decrease habitat complexity and diversity by removing large legacies (e.g., standing dead and downed logs), which can lead to an increase in insect activity (Hughes and Drever, 2001).

Furthermore, logging following insect outbreaks can seriously damage soil and roots by compacting them (see Lindenmayer *et al.,* 2008, for synthesis), leading to greater water stress. Soil damage resulting from logging with heavy equipment can increase the susceptibility of future forests to insects and disease (Hagle and Schmitz, 1993; Hughes and Drever, 2001), reduce conifer regeneration by increasing sapling mortality (Donato *et al.,* 2006) and, in general, cause more damage to forests than that caused by natural disturbance events (DellaSala *et al.,* 2006).