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Dendroctonus Beetles and Old-Growth Forests in the Rockies

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Abstract.--*Dendroctonus* beetles (Coleoptera: Scolytidae) are a major mortality agent in old growth pine, spruce-fir, and Douglas-fir forests of the Rocky Mountains. The frequency of recurring bark beetle epidemics depends on the size of the area being considered, how extensively the stand(s) was decimated by a previous epidemic(s), and how fast the stand(s) grows into the hazardous condition. Predictions of when epidemics will occur, their impact, and their duration are tenuous. Partial cutting may perpetuate old growth.

Dendroctonus beetles (Coleoptera: Scolytidae) are **the** significant mortality agent in old growth pine, spruce-fir, and Douglas-fir forests.[3] Different species of *Dendroctonus* have killed tremendous numbers of trees in the different forest types of the West. Mountain pine beetle (MPB) (*D. ponderosae* Hopkins) populations during the period 1979-1983 infested over 4 million acres per year in the western United States and killed over 15 million lodgepole pine (*Pinus contorta* Douglas ex Loud.) trees per year (McGregor 1985). The MPB killed over 15 million trees in 1981 in British Columbia (Canadian Forestry Service 1982). The same species killed over 1 million ponderosa pine (*P. ponderosa* Lawson) in the Black Hills in the 1963-1974 period (Thompson 1975). The spruce beetle (SB) (*D. rufipennis* (Kirby)) killed millions of Engelmann spruce (*Picea engelmannii* Parry) during the infamous White River outbreak from 1939 to 1951 (Massey and Wygant 1954). The Douglas-fir beetle (DFB) (*D. pseudotsugae* Hopkins) killed 109 million board feet of Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) between 1970 and 1973 (Furniss and Orr 1978). In essence, a destructive *Dendroctonus* species exists for each important coniferous species.

Effects of Epidemics

Bark beetle epidemics can decimate stands. Both the MPB and SB have killed over 90% of the live trees in a stand (Schmid and Frye 1977, McGregor et. al 1987). Mortality of this magnitude changes stand structure, species composition, and successional trends. For example, the MPB kills proportionately more large-diameter trees than small-diameter trees (Amman 1977) and thus alters the diameter distribution. Where lodgepole pine is the climax species, the MPB may create two- or three-storied stands (Amman 1977). Where lodgepole is seral, MPB epidemics may accelerate succession to other coniferous species in the absence of fire or, if fire occurs, help perpetuate the even-aged condition so conducive to extensive epidemics (Amman 1977). In the absence of fire in ponderosa pine stands in the Black Hills, paper birch (*Betula papyrifera* Marsh.) has become dominant in some old MPB epicenters (J.M. Schmid, personal observation).

In similar fashion, the SB has caused similar changes in spruce-fir stands. The White River SB epidemic killed 99% of the spruce over 10 inches d.b.h. (Schmid and Frye 1977) and altered species composition from 90% spruce-10% fir to 20% spruce-80% fir (Schmid and Hinds 1974).

Although major epidemics cause significant changes in stand structure over extensive areas, not all epidemics create these extreme impacts. Epidemics of lesser magnitude may kill 10% to 20% of the stand (Frye and Flake 1972) or only the largest-diameter trees within the stand (McCambridge et. al 1982). Mortality of this magnitude temporarily lowers the stand density by removing the large-diameter trees but may set up the stand for a more extensive epidemic in the near

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[3]Old growth as used herein refers to any stand with a number of susceptible-sized trees. Susceptible size may vary with different species of *Dendroctonus* but is generally a tree with a d.b.h. $\geq$8 inches.

future by creating more uniformity in diameter classes within the stand.

The death of the large-diameter trees, particularly in even-aged stands, generally means the loss of the overstory. This, in turn, allows understory vegetation to prosper. Herbage production of forbs, sedges, and grasses in a beetle-killed ponderosa pine stand increased to more than 500 pounds per acre in 3 years (McCambridge et. al 1982). Similarly, forbs, sedges, and grasses were denser in beetle-killed stands of spruce-fir than in green uninfested stands (Yeager and Riordan 1953).

The change in stand structure and the associated change in understory vegetation bodes well for some animal species and ill for others so the net result is diversity in animal species and their abundance. Species dependent on the old growth like the red squirrel (*Tamiasciurus hudsonicus* (Erxleben)) are adversely affected because of the loss of seed from the beetle-killed mature trees (Yeager and Riordan 1953). In contrast, chipmunks (*Eutamias* spp.) may benefit because of the increase in grasses and forbs. Wild ungulates may benefit from the increase in forage production in the short term but may not be able to use the forage in later years when fallen beetle-killed trees become an impenetrable jungle (Light and Burbridge 1985).

Populations of invertebrate and vertebrate predators of bark beetles may increase during the epidemic and then decrease dramatically after beetle populations become endemic. Foliage-gleaning birds such as chickadees (*Parus* spp.) and kinglets (*Regulus* spp.) as well as bark-gleaning birds such as nuthatches (*Sitta* spp.) and brown creepers (*Certhia americana*) decrease in number with an increase in beetle-killed trees once the infested trees lose their foliage. In contrast, woodpeckers (*Picoides* spp.) may temporarily increase with the increasing numbers of infested trees because of the insect fauna under the bark of the infested trees (Bull 1983). In general, the influence of beetle epidemics on animal species will vary depending on the needs of the particular species. Even then, the effects will vary depending on the extent (geographic area) and intensity (percent of stand killed) of the beetle epidemic.

Epidemics of *Dendroctonus* beetles have ramifications well beyond the tremendous number of dead trees. Extensive epidemics have increased annual streamflow 1.6 to 1.9 inches (about 16%) for a spruce-fir watershed (Mitchell and Love 1973) and water yield 15% for a lodgepole pine watershed (Potts 1984). However, net precipitation under small group infestations of the MPB was no different from under adjacent live trees (Schmid et. al 1991).

Both MPB and SB epidemics influence fire hazard and fire intensity, although fire hazard may be greater in pine stands than in spruce-fir stands. For both forest types, fire hazard is probably greatest during the two years following beetle attack when the dead needles and fine twigs are still on the trees. After needles and twigs fall, hazard decreases but still remains above pre-epidemic levels because of the increase in ground fuels. MPB epidemics create heavy fuel loads in lodgepole pine forests (Lotan 1976) and probably overshadow all other causes as a creator of fuel buildup (Lotan et. al 1985). This heavy fuel buildup increases the probability of high intensity fires (Brown 1975). SB epidemics also create heavy fuel buildups but fire hazard would not be as great as in beetle-killed pine stands except during the two years following beetle attack (Schmid and Frye 1977).

Frequency of Epidemics

Stands of dead trees in the pine and spruce-fir forests of the Rockies became the historical evidence of beetle epidemics from previous centuries when settlers immigrated into the forested regions. A SB outbreak killed mature Engelmann spruce on the Grand Mesa, Colorado, in the 1870's (Sudworth 1900) and MPB were infesting lodgepole pine in Utah around 1785 (Thorne 1935). One 400-year-old ponderosa pine tree showed evidence of seven unsuccessful MPB attacks during its life (Craighead 1925), thus indicating previous periods of MPB activity.

The historical evidence generally reflects *Dendroctonus* populations of epidemic proportions. But beetle populations are never in epidemic proportions continuously in a given stand. The frequency of epidemics depends on the size of the area being considered, how extensively the beetle population decimated the stand(s) within the area and modified its (their) stand structure, and how fast the stand again grows into the hazardous condition.

When the area under consideration is stand-size (i.e., 1-200 acres), the frequency of beetle epidemics depends on how extensively the previous epidemic decimated the stand. For example, some spruce stands subjected to the White River SB epidemic will probably be free of an outbreak of that magnitude for 150-200 years because 99% of the spruce over 10 inches d.b.h. were killed (Schmid and Frye 1977). Similarly, where a MPB epidemic killed 84% of the pine basal area in 163 acres of ponderosa pine and reduced the basal area to 27 ft^2 per acre (McCambridge et. al 1982), the stand(s) would not be expected to suffer another outbreak for 50-100 years. In contrast, a stand surviving a short-lived epidemic or losing 10-20% of its basal area may be subjected to another epidemic within 20-50 years.

When the area under consideration is more regional such as river drainages or districts of national forests, the interval between epidemics is less. Intervals between MPB epidemics in ponderosa pine on the Kaibab National Forest ranged from 4 to 14 years from the end of one epidemic to the start of another (Blackman 1931), but the epidemics were not at the same locale. Frequency of MPB epidemics in lodgepole stands range from 20 to 40 years for any given area (Cole and Amman 1980). In ponderosa pine in the Black Hills, the frequency between epidemics was 5-35 years (Thompson 1975), but again the infestations were not in the same locale.

Intervals between epidemics can obviously be misleading because the duration of epidemics is also frequently contingent on what area is defined as common to each epidemic as well as our definition of the start and ending of epidemics. DFB epidemics generally last only 3-4 years (see McGregor et. al 1974) while the duration of MPB epidemics is variously estimated as: 6 years in lodgepole pine (Cole and Amman 1980), 7-12 years (Coulson et. al 1985), 2-5 years for short-term epidemics in ponderosa pine (see Blackman 1931), 7-13 years (see Blackman 1931) and 13 years (McCambridge et. al 1982) for long-term epidemics in ponderosa pine.

Although MPB epidemics in lodgepole pine usually last less than 10 years, epidemics may last for $\geq$30 years for the lodgepole type as a whole (G.D. Amman 1992, personal observation). For example, a MPB epidemic was reported on the Flathead National Forest in northwest Montana in 1909. During the succeeding 25 to 30 years, new infestations appeared in most national forests and parks between Flathead and the Cache National Forest in northern Utah (Evenden 1934). More recently, the reverse occurred with epidemics starting in the Wasatch National Forest in northern Utah about 1955 and eventually arising in most national forests and parks between Wasatch and the Kootenai National Forest in northern Montana over the next 35 years (G.D. Amman 1992, personal communication).

Intervals are also complicated by the imprecise definition of when beetle epidemics begin and end, particularly in records before World War II. Even records of epidemics as recently as the 1960's and 1970's can be interpreted differently. Thompson's 1975 review of MPB activity in the Black Hills led him to believe that epidemics occurred in 1962, 1967, and 1972. These three MPB epidemics could also be considered one epidemic with various infestation loci caused by shifting MPB populations as well as lulls and increases in population levels during the epidemic phase. (J.M. Schmid 1992, personal observation).

Endemic Population Levels

Between epidemics, bark beetle populations are endemic, i.e., at a level where their presence is hardly noticeable. They exist in trees predisposed to attack by biotic agents or weather phenomena. MPB populations in lodgepole stands cohabit in trees previously infested by other small scolytids such as *Ips pini* (Say), *Pityophthorus confertus* Swaine or *Pityogenes knechteli* Swaine (Schmitz 1988), or in trees infected with *Armillaria* root disease (Tkacz and Schmitz 1986). In ponderosa pine in the Black Hills and southern Utah, endemic MPB populations can be found in *Armillaria*-infected trees or in lightning-struck trees. SB populations inhabit wind-thrown or wind-damaged trees. DFB populations are also associated with wind-thrown trees as well as diseased and defoliated trees (Furniss et. al 1981).

On first thought, the incidence of predisposing weather or biotic phenomena would seem so infrequent that beetle populations would have difficulty maintaining themselves. However, weather phenomena are more insidious than might be imagined. Wind conditions in the central Rockies characteristically reach hurricane velocity at least once each year. Conceivably, winds of this magnitude would wind-throw a tree or tear the top from a mature spruce or Douglas-fir somewhere in every 200-300 acres. Both tree conditions would be suitable habitat for maintaining SB or DFB populations.

Similarly, lightning directly and indirectly predisposes trees. Lightning strikes from summer storms may average one per 20-50 acres in the Black Hills (R. Holle 1992, personal communication) and lightning-struck trees are potential sites for MPB infestation (J.M. Schmid

1992, personal observation). Lightning-caused fires scorch trees and thereby predispose them to beetle infestation (Fellin 1980, Amman and Ryan 1991), which in one case led to a DFB epidemic (Furniss 1941). Lightning-caused fires predispose trees to infection by root rot fungi, which subsequently predispose trees to beetle infestation (Gara et. al 1985). These various weather influences plus the number of trees predisposed by *Armillaria* and other scolytids could sustain MPB populations.

Because endemic bark beetle populations exist in the forest, their recurrence at epidemic levels in any particular stand becomes mostly a function of how quickly that stand reaches a hazardous state. As noted previously, this depends primarily on how extensively the previous epidemic modified the original stand structure. To a lesser extent, post-epidemic tree and stand growth will also influence how quickly the stand will return to the high hazard condition. If other disturbances such as fire, logging, etc., are injected into the stand development scenario, they may further affect the development of the hazardous state.

Hazardous Conditions

Highly hazardous stand conditions vary among *Dendroctonus* species but also have some striking similarities. For the MPB in lodgepole pine, stands with a number of large-diameter trees are hazardous (Cole and Amman 1969). More specifically, stands with average d.b.h. >8 inches, average age >80 years, and low elevation-latitudes are considered high risk (Amman et. al 1977, Hall 1985) when they are within the most suitable climatic zones of Safranyik et al. (1974). Stands of ponderosa pine with basal areas ≥ 150 ft^2 per acre and average d.b.h. ≥ 8 inches are considered highly hazardous for MPB infestations (Sartwell and Stevens 1975), although recent evidence suggests a basal area ≥ 120 ft^2 coupled with an average d.b.h. ≥ 8 inches may constitute the critical threshold (Schmid and Mata 1992). Spruce-fir stands are highly hazardous for SB infestations when the basal area >150 ft^2 per acre, average diameter >16 inches for live spruce above 10 inches d.b.h., proportion of spruce in the canopy $>65\%$, and their physiographic location is a well-drained site in creek bottoms (Schmid and Frye 1976). High density Douglas-fir stands composed of ≥ 120 year-old large-diameter trees are highly hazardous for DFB epidemics (Furniss et. al 1981). More specifically, stands with average diameter ≥ 16 inches d.b.h., basal area ≥ 150 ft^2 per acre, and age ≥ 100 years are highly hazardous when they are near root disease centers (K.E. Gibson 1992, personal communication).

Predicting Epidemics

Given a highly hazardous stand, can we predict when an epidemic will begin? Not really, at least not without supplemental information. Predicting an epidemic for any of these *Dendroctonus* species is like predicting a 100-year flood. We know that it will happen sometime during the next 100 years after a number of trees reach susceptible size, but we can't pinpoint the exact year. We can't predict the year of an epidemic because we don't precisely know the key factor(s) that trigger the change from the endemic to the epidemic. We can with *Dendroctonus* beetles, however, make shorter term predictions for the start of future epidemics if we have supplemental information. For example, the SB and DFB prefer to inhabit downed trees and most epidemics have arisen from populations originating from downed trees (Schmid and Frye 1977, Furniss et. al 1981). If a windstorm creates substantial wind-thrown or wind-broken trees in a high-hazard forest supporting endemic SB or DFB populations, then we would expect to see the start of an epidemic (some infested standing trees) 4-6 years after the blowdown. Without the information on windthrow, the forecast of an epidemic for either the SB or DFB would be more tenuous.

We also cannot predict with much certainty the duration of the epidemic and, therefore, the extent of the tree mortality in ponderosa pine, spruce-fir, and Douglas-fir stands. The duration of an epidemic is uncertain because our ability to predict population trend is limited to one year into the future (see Knight 1959, Knight 1960a, 1960b). Thus, given the start of an epidemic, we can predict the population level and its associated level of tree mortality one year hence but not how long a specific epidemic will last or the eventual magnitude of the tree mortality. However, we can do somewhat better for lodgepole pine because the duration of the MPB epidemic and its associated tree and volume losses can be estimated on an annual basis (Cole and McGregor 1983). For all *Dendroctonus* species, we can outline for the forest manager a series of epidemic scenarios and their respective levels of tree mortality based on the current stand conditions and historical evidence from past epidemics.

Beetle Management

Although our predictive capabilities for epidemic startup and duration are tenuous, our ability to minimize tree mortality through silviculture is substantially greater. For the MPB at least, partial cutting greatly reduced tree losses (fig. 1) in stands of lodgepole pine (McGregor et. al. 1987) and ponderosa pine (Schmid and Mata 1992). Maintaining ponderosa pine stands at basal areas of $\leq$100 will minimize tree mortality (Schmid and Mata 1992).

The success of partial cutting against the MPB in 80- to 125-year old pine stands suggests it could be used to perpetuate old growth pine stands. And we assume similar practices would be effective against the SB in spruce-fir stands and the DFB in Douglas-fir stands because DFB outbreaks have not been evident following any kind of commerical cutting (Furniss et. al 1981). However, over time, stands will grow into a hazardous state. How long the partial cutting will effectively maintain minimal losses is a function of the stand density (basal area) and tree growth subsequent to cutting (Schmid 1987) but we know the partially cut lodgepole pine stands of McGregor et. al (1987) have remained relatively free of MPB infestation since cutting (12 years). Using RMYLD (Edminster 1987), we can project when partially cut stands of various densities will reach the critical thresholds and become susceptible again. Assuming a basal area of 150 as the critical threshold for MPB epidemics (Sartwell and Stevens 1975), stands cut to basal area 60 would remain unsusceptible for 60-80 years, basal area 80 for 40-50 years, basal area 100 for 25-40 years, and basal area 120 for <20 years (Schmid 1987). However, if the critical threshold is basal area 120 rather than 150 as Schmid and Mata (1992) propose, then stands would become highly hazardous much sooner; namely, about 50 years for basal area 60 stands, 25-30 years for basal area 80 stands, and 11-15 years for basal area 100 stands (table 1). Thus, stands may grow into a high hazard condition rather quickly, depending on their density.

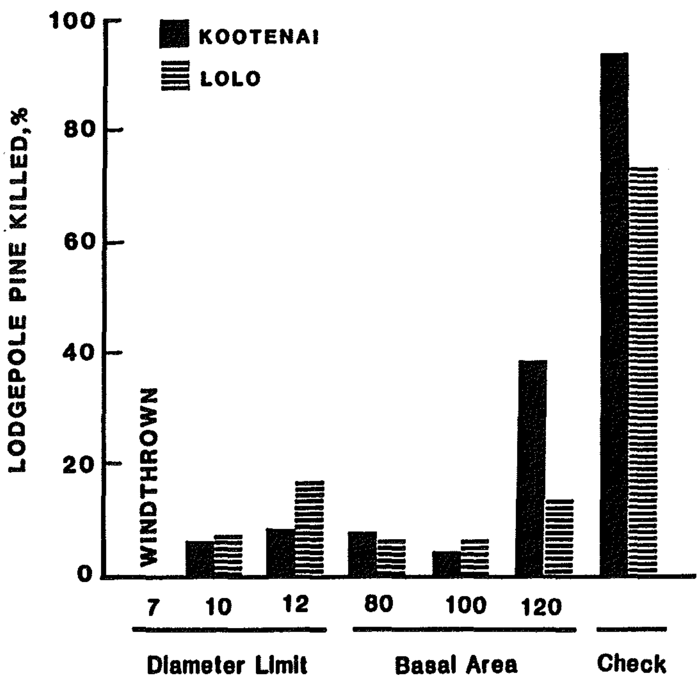

Figure 1.--Percent lodgepole pine (LPP) killed by mountain pine beetles in different partial cutting treatments, Kootenai and Lolo National Forests, Montana, 1980-1984 (from McGregor et. al 1987). Treatments indicate diameter limit cuts in which all trees $\geq$7, $\geq$10 or $\geq$12 inches (d.b.h.) were removed, spaced cuttings leaving basal areas of 80, 100, or 120 ft^2 per acre, and uncut check.

Table 1.--Time required for partially cut stands of specific GSLs to reach basal areas (BA) of 120 and $\geq$150 ft^2 per acre as projected by RMYLD. Mean diameter (D) for each GSL under BA 120 and $\geq$150 represents the projected diameter when each GSL reaches those basal areas.

Area/ growing stock level	Stand conditions BA	Stand conditions Mean D	BA 120 Time	BA 120 Mean D	BA >150 Time	BA >150 Mean D
	(ft/ac)	*(in)*	*(yrs)*	*(in)*	*(yrs)*	*(in)*
Brownsville (PP)						
60	60.5	12.4	51	18.0	76	19.5
80	80.8	11.5	29	13.4	51	15.7
100	100.7	12.8	16	14.0	37	15.6
Hinman (LP)						
80	79.8	12.8	24	15.8	40	17.6
100	101.2	12.7	11	13.9	27	15.5
120	118.1	10.9	1	11.0	13	12.3
Brush Creek (LP)						
40	40.0	9.8	73	17.7	90	19.6
60	60.7	12.0	48	17.0	62	19.9
80	81.3	10.0	26	11.2	40	13.6
120	119.7	8.9	4	9.2	16	10.2
White House (PP)						
60	59.0	12.5	50	18.0	75	20.1
80	79.0	11.5	19	13.8	51	15.5
100	100.7	11.6	14	13.6	35	14.4

Although the high hazard condition in managed stands[4] should be a red flag for forest managers and should stimulate silvicultural action, stands may exist in this state for years before beetle populations become epidemic. If annual forest pest management surveys reveal no change in the endemic status, then no action is necessary. However, if surveys indicate increasing trends in beetle populations, then forest managers must act promptly, particularly in pine stands where populations can rapidly increase and spread to adjacent areas. Forest managers will not be able to maintain old growth forever, and some trees will be lost even after partial cutting, but managers can extend stand life beyond the time when bark beetles perform their regulatory cut. The bottom line is, Will the general public allow forest managers to minimize beetle-caused mortality through partial cutting in order to perpetuate the old growth? Or, rephrased, Who will do the cutting--the forest manager or the beetles?

[4]Managed stands as used herein refer to stands in which silviculture is practiced, wildfires may be suppressed and insect infestations are managed.

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