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Hazard-Rating Systems in Forest Insect Pest Management:

Symposium Proceedings

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HAZARD-RATING LODGEPOLE PINE FOR SUSCEPTIBILITY TO MOUNTAIN PINE BEETLE INFESTATION

Mark D. McGregor, Gene D. Amman, and Walter E. Cole[1]

Abstract.--In 1975, Montana stands of lodgepole pine, *Pinus contorta* var. *latifolia* Engelmann, were rated using Amman's system for risk of infestation by mountain pine beetle, *Dendroctonus ponderosae* Hopkins. Hazard rating was based on three factors--climate suitability of the stand, average d.b.h., and average tree age. The system helped direct land managers to susceptible stands where harvest of trees is reducing losses to the beetles. During the 5 years following rating, 11 percent of the high-hazard stands became infested; only 1 percent of the stands rated moderate became infested; and less than 1 percent of the stands rated light became infested.

INTRODUCTION

Forests of lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) provide important cover on more than 13 million acres (5.2 million ha) in 11 Western States (Wellner 1975) and over 49.5 million acres (19.8 million ha) in western Canada (McDougal 1975). This forest cover serves many purposes, such as scenic backdrops for recreational areas, protection for watersheds, habitat for game animals, areas for domestic livestock grazing, and raw materials for lumber, poles, posts, and pulp (Tackle 1954). Lodgepole pine has a wide geographic range, extending from Alaska south to northern Baja, California, and east through Wyoming and Colorado. It can be found from sea level in Alaska to 11,500 ft (3,485 m) in Colorado, although it grows best where the annual precipitation is 21 inches (52.5 cm) or more (Mason 1915).

Prior to World War II, lodgepole pine was considered a weed species and of little value (Wellner 1978). Since that time, commercial importance has increased considerably in Montana, Idaho, Wyoming, and Colorado--the States with over 80 percent of the lodgepole pine in this country --and also in Utah and Oregon (Wikstrom 1957).

With lodgepole's increasing importance, managers have become more conscientious about its protection and perpetuation. Without protection and management, lodgepole pine forests are transient pioneers giving way to natural factors such as insects, diseases, and in the absence of wildfire, to succeeding vegetation (Roe and Amman 1970).

Infestations of the mountain pine beetle (MPB) (*Dendroctonus ponderosae* Hopk.) are probably the most important natural factor affecting lodgepole pine. This pest makes it very difficult to convert unmanaged to regulated forests with even-flow, sustained yield (Wellner 1978). During the past few decades, the beetle, rather than the manager, has set priorities and cutting schedules.

The MPB is indigenous to North America and probably has been active in lodgepole pine ecosystems almost as long as the tree has existed. Endemic beetle populations infest windthrown lodgepole pine with roots still intact; lodgepole pine affected by root pathogens, dwarf mistletoe, rust fungi, defoliators, drought, porcupines; and trees partially infested with secondary bark beetles. Once the stand attains conditions conducive to beetles (i.e., large-diameter trees and thick phloem), an epidemic begins. Attacks are concentrated on open-grown, large-diameter trees ≥ 80 years old, with thick phloem, in habitat types and at elevations suitable for both good lodgepole pine growth and beetle survival.

MPB infestations in a given area generally occur about every 20 to 40 years, depending on how rapidly stands of trees grow to large diameters containing thick phloem and have other conditions favorable for beetle development (Amman 1977). For example, the southern end of the Targhee National Forest in southeastern Idaho was subjected to an epidemic infestation of MPB in the late 1950's and early 1960's. After most of the large-diameter lodgepole pine were killed, the beetle population subsided. Now, some 20 years after the beginning of the previous infestation, another epidemic has started.

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HAZARD-RATING SYSTEMS

Systems for rating the risk of MPB outbreaks in lodgepole pine forests usually have been based on (1) historical evaluation of the frequency and intensity of infestations within a region; (2) correlation of damage intensity and habitat type; (3) evaluation of damage by climatic zones; (4) host tree characteristics, including diameter and phloem thickness; (5) stand characteristics, including crown competition, periodic growth rate, and basal area; and (6) various combinations of these factors.

A map of relative stand hazard from MPB has been developed for the central and northern Rockies, based on the frequency and intensity of past infestations (Crookston et al. 1977). The map is useful in drawing attention to stands in areas that have suffered repeated severe outbreaks, so that these stands can be rated using specific hazard-rating systems.

Beetle-caused tree mortality has been related to habitat types (Roe and Amman 1970). The risk of growing trees to a specific diameter was considered the product of the proportion of trees killed in a diameter class times the proportion of stands on a given habitat type that showed evidence of prior infestation. For example, growing trees to 16 inches (40.6 cm) d.b.h. would be a high hazard (75 percent probability of loss) on *Abies lasiocarpa/Pachistima myrsinites* type, where 82 percent of the trees were killed and 92 percent of the stands were infested. In contrast, the hazard of growing 16-inch d.b.h. trees on the *Abies lasiocarpa/Vaccinium scoparium* type would be much less, with about two-thirds of the trees expected to survive (36 percent probability of loss). However, because of the elevation range in some habitat types and corresponding range in MPB-caused mortality (McGregor 1978), elevation must also be considered in hazard rating. Where management plans are being developed in Region 1, habitat type and elevation are included in stand hazard rating.

Safranyik et al. (1974) used weather data to define hazard by climatic regions in British Columbia. Where climatic conditions were highly conducive to outbreaks, stand susceptibility was further evaluated using age and tree diameter. Although similar maps have not been developed for the central and northern Rocky Mountains, the effects of climatic conditions throughout the region were taken into account with the system developed by Amman et al. (1977).

Tree diameter and phloem thickness were used in a hazard-rating system to assess beetle population potential within three infested areas in Colorado (Cole 1978, Cole and Cahill 1976). Observations in these stands suggest that where 20 percent of the trees ≥ 8 inches (10 cm) d.b.h. in a stand have a phloem ≥ 0.11 inch (2.79 mm) thick, the stand has the potential for significant MPB outbreaks and should be considered for harvesting.

Mahoney (1978) mentions the investigations of Schenk et al., who used stand characteristics, crown competition factor (CCF), and percent of basal area in lodgepole pine (LPPBA) for a stand hazard rating (SHR) system in western Montana and northwestern Idaho. The formula is

$$SHR = CCF \times \frac{\%\ LPPBA}{100}$$

Schenk's team reported good agreement between the stand hazard rating and lodgepole pine mortality in stands they measured. Mortality increased with increased crown competition and BA in lodgepole pine. However, this relation did not hold when the rating system was used for lodgepole pine in Montana, southeastern Idaho, and northwestern Wyoming (McGregor 1978), where infestations have been more intense in open rather than dense stands. Data from stands in Montana show that as crown competition increases, lodgepole pine mortality decreases (fig. 1).

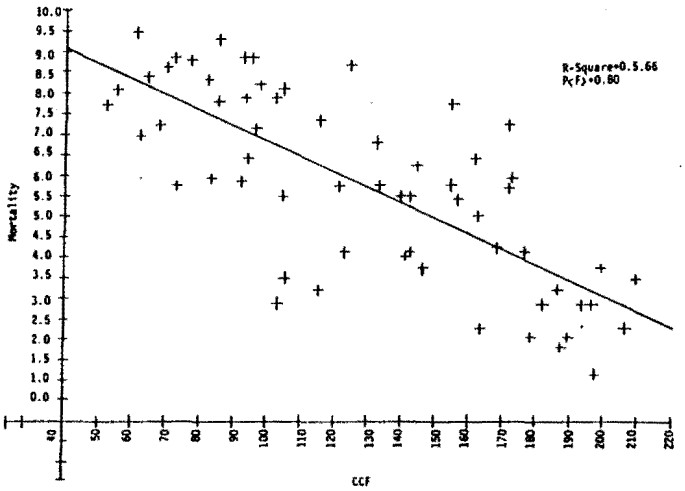

Figure 1.--The relationship of lodgepole pine to CCF for 62 stands in Montana, 1978-79. Note: Data transformed,

$$Y' = \sqrt{Y + 3/8}$$

Periodic growth ratios (PGR) also have been suggested as a means of evaluating stand susceptibility to MPB (Mahoney 1978). The formula is

$$PGR = \frac{\text{Current 5-year radial increment}}{\text{Previous 5-year radial increment}}$$

PGR is considered a measure of current trend in stand vigor. Values > 1.0 indicate rising growth and vigor and < 1.0 indicate a decline in vigor. A PGR value of < 0.9 is considered a decline in vigor that indicates a lodgepole pine stand which will support an increasing MPB population and sustain an epidemic (Mahoney 1978).

Mahoney found good agreement for PGR and beetle activity in 21 stands in northern Idaho and western Montana. However, PGR does not distinguish among fast- and slow-growing trees. For example, suppressed and dominant trees can have the same PGR, but the dominant group obviously is in much better health and will have thicker phloem. Mahoney (1978) stated, "Lodgepole pine stands that are growing relatively well, but suffer a decline in growth rate, should provide trees with thick phloem, but lowered resistance due to decline in PGR." However, we feel a decline in PGR is not necessary since we have observed infestations to start following an increase in tree growth sustained over a long period of time (Amman 1978).

AMMAN'S HAZARD-RATING SYSTEM

Amman's hazard-rating system (1977) for MPB in lodgepole pine is based on three factors: (1) climatic suitability (elevation and latitude of the stand for outbreak development, (2) average stand age, and (3) average stand d.b.h.

The rationale behind using these factors is as follows. Beetle populations do well at low elevations where temperatures are optimum for development. Development of the beetles slows as elevation increases, until at high elevations 2 years may be required to complete a generation (Amman 1973). If development is delayed, beetles may overwinter in life stages vulnerable to the harsh climate. In addition, beetles in a 2-year cycle are subjected to mortality factors for twice as long as those in a 1-year cycle. These adverse effects on the beetle population are reflected in reduced tree mortality at high elevations.

Climatic suitability is based on lodgepole pine losses to MPB observed at many different elevations and latitudes from Colorado to the Canadian border (fig. 2).

These data were plotted by elevation and latitude and separated into three loss classes--low risk when 25 percent or fewer lodgepole pine of commercial size (8.5 inches [22 cm] and larger d.b.h.) were lost; moderate risk when 25 to 50 percent of the commercial lodgepole were killed; and high risk when more than 50 percent of the commercial lodgepole were killed.

Average age of the stand enters into the picture, not as a measure of tree vigor, but rather of phloem suitability. Young trees, usually those less than 60 years of age, have phloem more spongy and resinous than older trees. Young trees tend to dry excessively after being infested and killed by the beetles. These characteristics are less apparent in trees between 60 and 80 years old. Trees over 80 tend to have phloem that is considerably firmer and contains fewer and smaller cortical resin ducts. Such trees generally dry slower than young trees, thus providing adequate moisture throughout beetle development.

Average d.b.h. is used because of the beetle's strong preference for large-diameter trees. These trees generally have thicker phloem and dry slower than small-diameter trees. MPB brood production is strongly influenced by phloem thickness and moisture in the tree (Cole et al. 1976).

Average d.b.h. of < 7 inches (18 cm) presents a low hazard; between 7 and 8 inches (18 to 20 cm), a moderate hazard; and > 8 inches (20 cm), a high hazard. Of these categories, only stands averaging ≥ 8 inches d.b.h. can be expected to have a sufficient number of large-diameter trees for the MPB population to build up and be sustained. The first two hazard

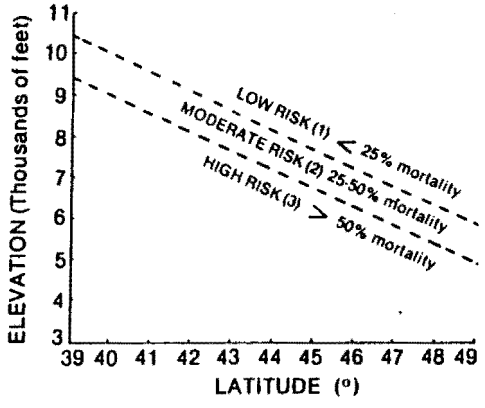

Figure 2.--Risk of mountain pine beetle infestation in lodgepole pine can be defined by zones of elevation and latitude. Percent mortality is for trees 8.5 inches (22 cm) d.b.h. and larger (Amman et al. 1977).

categories have fewer large trees, resulting in lower beetle populations and hence reduced tree losses.

Average elevation, stand age, and d.b.h. are obtained during a standard forest cruise. For small stands of under 20 acres (8.1 ha), a systematic random sample of 10 variable plots (10 BAF) is used. For larger stands, 20 variable plots are used. Field crews determined tree age by taking an increment core at breast height from the three trees closest to plot center that are 5 inches (13 cm) d.b.h. or larger. Average diameter is calculated from the diameters of all "in" lodgepole pine trees ≥ 5 inches (13 cm) in d.b.h.

Risk values have been assigned to each of three factors--climatic suitability, average tree age, and d.b.h. (table 1). This system has been valuable for stands hazard-rated on the Gallatin and Kootenai National Forests in Montana.

APPLICATION OF AMMAN'S SYSTEM

In 1975, 3 years after the start of an MPB epidemic, lodgepole pine stands on the Yaak Ranger District, Kootenai NF, were hazard rated for infestation potential. Hamel and McGregor (1976) based the rating on average age of lodgepole pine, average tree diameter, and elevation and latitude. Inventory data collected during 1977 and 1978 were used to update the original hazard classification and to produce a hazard map for the Kootenai NF in 1978. Calculations of susceptible areas showed 278,782 acres (112,867 ha) of high hazard; 56,656 acres (22,937 ha) of moderate hazard; and 93,699 acres (37,934 ha) low hazard. Table 2 shows infestations by year, in areas rated high, moderate, and low hazard.

In 1975, 5,110 of the 278,782 acres classed high-hazard were infested; no moderate- or low-hazard type was infested. By 1979, 29,413 acres (11 percent) of the high-hazard type, 455 acres (1 percent) of moderate hazard, and 26 acres (< 1 percent) of low hazard were infested. Lodgepole pine classed moderate and low hazard did not become infested until 1977, 5 years after the epidemic started.

Following rating, NF personnel assigned harvest priorities to high-hazard stands with a significant number of lodgepole pine ≥ 60 years old.[2] Table 3 gives the volume of lodgepole pine removed from these stands since 1976. Management for each stand includes salvage logging of infested trees and cutting the susceptible stands prior to beetle infestation.

We feel that implementing hazard-rating surveys and subsequent harvesting of the susceptible lodgepole pine stands have helped slow the infestation on the Kootenai NF. As a result, fewer acres have been infested and fewer trees have been killed (McGregor 1978).

USING HAZARD RATING IN FOREST SYSTEMS

When systems of hazard rating were being developed, it was expected that Forest Pest Management units would be responsible for them. Amman's system did require coordination between FPM groups from Regions 1, 2, and 4 with the Bark Beetle Research Group at the Intermountain Forest and Range Experiment Station, Ogden, Utah, in pooling of field data for development and validation of the system.

When the system was first used in Region 1, FPM worked with two National Forests to hazard rate lodgepole pine type with the old timber type maps, which were only 60 percent accurate at best. As new data became available from Stage I and Timber Inventory Surveys, and compartments, subcompartments, and stand maps were developed, there was a basis for updating the old timber type maps and for hazard rating individual lodgepole pine stands.

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[2] Personal communication, John R. Naumann, Silviculturist, Kootenai National Forest, 1976.

Table 1.--Factors for rating lodgepole pine for the risk of mountain pine beetle infestation in Montana. By multiplying the following risk factors (1 = low; 2 = moderate, 3 = high) for elevation and latitude, average age, and average d.b.h., the stand's susceptibility classification is obtained; low = 1 to 6; moderate = 8 to 18; high = 27.

	RISK CLASSIFICATION		
	Low = 1	Moderate = 2	High = 3
Elevation-latitude	High	Moderate	Low
Average age (years)	<60	60-80	>80
Average d.b.h. (inches)	< 7	7-8	> 8

Table 2.--Mountain pine beetle infestation on the Kootenai National Forest, 1975-79

Hazard class	1975 Acres	1975 Percent infested	1976 Acres	1976 Percent infested	1977 Acres	1977 Percent infested	1978 Acres	1978 Percent infested	1979 Acres	1979 Percent infested
High	5,110	2	17,638	6	10,863	4	20,562	7	29,413	11
Moderate	0	0	0	0	827	1	495	1	455	1
Low	0	0	0	0	10	<1	615	1	26	<1

Table 3.--Volumes of lodgepole pine removed from stands hazard rated on the Kootenai National Forest, 1976-80.

Year	Acres harvested	Fbm removed
1976	3,585	28,000
1977	1,600	21,000
1978	1,495	17,000
1979	5,400	463,000
1980[1]	8,400	72,000

[1] Figures for 1980 represent harvest for the period 1979 through fall of 1980. Fiscal year 1980 harvest is estimated at 8,400 acres containing 72,000 fbm of lodgepole pine (Jerrold Park, Silviculturist, Kootenai NF, 1980, personal communication).

Status of Hazard Rating in Region 1

All lodgepole pine type on National Forests in Montana has now been hazard rated by Amman's system. As Unit and District plans are developed and integrated into the overall Forest Management Plan, rating is being done on a stand-by-stand basis.

During the past 2 years, FPM in Region 1 has cooperated with forest inventory crews in collecting stand data that will provide the necessary information for hazard rating individual stands. Raw field data sent to the FPM office are card punched by Computer Science and analyzed in a program developed by statisticians in FPM. This program provides a hazard rating for each surveyed stand. The land manager then receives a listing of stands with high, moderate, and low risk to MPB infestation.

Then an interdisciplinary team, with specialists on timber, silviculture, recreation, wildlife, soils, geology, hydrology, fire, FPM, transportation, and public information, develops an environmentally acceptable plan for reducing losses to the MPB and other insects and diseases--a plan that relates to other forest management activities. This plan provides the manager with guidelines for assigning priorities to timber sales, road building, and cutting schedules in and near lodgepole pine stands.

The rating system may be used on both public and private lands. Hazard criteria can be applied by silviculturists and timber management planners without extensive training. Demonstration areas have been set up in lodgepole pine stands in many areas of the Intermountain Region. Data from the demonstration areas have helped users accept the system as they can review and evaluate the results of cutting strategies based on the stand hazard predicted by the rating system (Emerson 1979).

Performance of the hazard-rating system and management effort's to reduce losses will be monitored and modified as new information becomes available.

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