Progress in Pine Beetle Control Through Tree Selection

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The possibilities of pine beetle control through tree selection are being established. This method involves the removal of high risk trees from the stand. But what are high-risk trees and how may they be recognized? Several investigators, especially Dunning, Keen, and Salman and Bongberg, have developed tree classification systems, primarily silvicultural in character and operation, but with emphasis on the entomological phases of silvicultural problems. The authors describe the various tree classifications that have been proposed and their application to bark beetle control.

A RECENT paper (*10*) describes the latest development in the search for effective methods of controlling the western pine beetle (*Dendroctonus brevicomis* Lec.) and associated insects that have been responsible for killing vast quantities of ponderosa pine in the forests of California, Oregon, Washington, and Idaho. Foresters and timber owners have realized for many years that unless losses resulting from the activity of these insects could be materially reduced, there was little hope of attaining sustained-yield objectives or of putting pine-forest management in these areas on a permanently productive basis.

Because of the importance of this pine beetle problem the Bureau of Entomology and Plant Quarantine, through its Division of Forest Insect Investigations, has directed towards its solution much of the research at its Berkeley, Calif., and Portland, Oreg., field laboratories. Many different lines of attack have been tried. Many promising leads have failed, but through the years we have gradually obtained a fuller understanding of the principles and factors underlying this problem and we know what lines of attack now offer the most promise of success. Thus the present development may be regarded as the outcome of the research that has gone before and a culmination of many previous lines of work.

The purpose of this article is to explain how this latest method of pine beetle control through the use of light sanitation salvage cuts is related to and advances previous work along this line, particularly what relationship there may be between the 4 risk ratings proposed by Salman and Bongberg (*10*) and the 16 tree classes previously set up by Keen (*5*) as a basis for judging the susceptibility of ponderosa pines to bark beetle attack. In order to clarify the picture it is necessary to review briefly the forest-insect control problem in ponderosa pine, particularly as it applies to the Oregon and California region, and the research that has led up to these more recent developments of indirect control methods.

Review of Past Studies

The first methods of western pine beetle control were those proposed by Hopkins in 1909 (*4*). These consisted of reducing bark beetle populations by destroying broods either by felling, peeling, and burning infested trees or by removing them to mills and destroying the bark-infesting beetles in the millpond or in the refuse burner. These direct control methods have been in use ever since wherever aggressive beetle outbreaks have occurred and where pine timber is of sufficient value to warrant the expense of control operations. While the results of such work have been temporarily effective against epidemic infestations, they have not been entirely satisfactory because no lasting benefits accrued (*2*). In order to provide a longer period of protection, maintenance control was then tried. Under this plan, control, using the fell-peel-burn method, was continued for several years on one area with the idea of holding the infestation down and preventing any increase. The unpublished results of this work reveal that although western pine beetle populations could be greatly reduced and maintained at a low level, the cost of such protection was excessive when compared with the commercial timber values that were saved. Maintenance control is therefore warranted chiefly in parks and recreational areas where high values are placed on tree cover.

Several other direct control methods have been tested experimentally in the hope of increasing the effectiveness and lowering the cost of control. Person (*8*) tested solar-heat treatments designed to kill the bark beetles but to preserve the predaceous larvae of the black-bellied clerid (*Thanasimus lecontei* Wolc.). This method was only

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partially effective, and its application seemed to be suited chiefly for summer control work under special conditions. Salman (*9*) found that certain oil sprays applied externally to the bark of felled, infested trees had control possibilities, but that this method was not well adapted for general application.

The trouble has been that none of the direct control methods applied in the field or tested experimentally affected the basic underlying causes of bark beetle epidemics (*2*). Even though beetle populations have been greatly reduced, either by artificial control or natural causes such as extremely low temperatures, the residual beetle population has had remarkable powers of rebuilding to former levels. Thus there seemed to be little hope of lasting results with any method which depended entirely on destroying beetle populations, and gave no consideration to the underlying causes of attack or the natural susceptibility or resistance of the host tree.

For this reason studies were begun to determine what were the underlying causes of bark beetle outbreaks. Were they biological, ecological, climatic, silvicultural, or physiological in character? Could control be obtained through some modification of one or more of these factors? Were certain trees more attractive to the beetles than others? Could a tree's resistance to attack be increased? These were some of the questions that were investigated in the hope of finding new leads in solving the problem of reducing losses in ponderosa pine stands.

While there were many factors involved, one of the first things observed by forest entomologists and silviculturists was that the western pine beetle exhibited definite tendencies toward selecting the more mature, slow-growing, and decadent trees for attack and avoided the younger, thriftier, fast-growing individuals. Hopkins was probably the first to call attention to this characteristic, for in his treatise on *Dendroctonous* in 1909 (*4*, p. 25) he says: "Practically all of the more destructive species [of *Dendroctonus*] show a decided preference for the larger and best-matured trees, and as a rule these are killed first, and the younger timber is not attacked until later, if at all." The work of Miller, Keen, Patterson, and Person, as reported by Craighead (*1*) in his analysis of the *Dendroctonus* problem in 1925, confirmed this general observation to the effect that the western pine beetle preferred over-mature, slow-growing, decadent trees, particularly those growing on the poorer sites, and first suggested the application of those observations to the management of the ponderosa pine type.

Dunning (*3*), in connection with the description of his tree classification, inquired into the relative frequency of beetle damage in different classes of trees, and found that the older trees and those making poor growth were more frequently killed by insects than trees of the younger and more vigorous classes.

Person (*6*) contributed additional evidence by comparing the growth rates of insect-killed and living trees, and found that losses were heavier on the poorer sites and that the trees selected by the western pine beetle for attack were those of inferior vigor and, on the average, making a radial growth of less than 1 mm. per year.

While all these observations and studies showed that the beetles did select certain types of trees for attack, they did not explain why this occurred, what attributes these trees had that made them attractive to the beetles, or how the more susceptible types or individual trees could be recognized with any degree of certainty.

Investigating this phase of the problem Person, Jeffrey, Mirov and Gordon, and others tested the western pine beetle for positive tropisms and conducted experiments in its attraction to different host materials. Person (*7*) found that fermenting phloem was especially attractive to the western pine beetle, and that a species of yeast which is almost constantly associated with larval and adult stages of the western pine beetle might reasonably cause a fermentation of the phloem and induce subsequent attacks. He reported the work of Jeffrey, who found that susceptible trees contained higher proportions of the reducing sugars, chiefly levulose, in their phloem.

In subsequent studies conducted in northeastern California on the characteristics of infestations in attacked trees Salman, Bongberg, and others found that a sequence of attacks by more than one species of insect usually occurred. Top-killing by engraver beetles (*Ips oregoni* Eichh.) and by the California flathead borer (*Melanophila californica* V.D.) in particular seemed to precede bark beetle attack. Later studies have shown that flathead borer broods are present and feeding in the cambium region of many susceptible green trees long before such trees are attacked by bark beetles. Salman and Bacon reported in 1933 (unpublished) that the growth rates of infested trees apparently showed less relation to environmental stimuli than did those of comparable uninfested trees.

The results of all these studies indicated that susceptible trees may be attractive to bark and cambium miners because of their poor physiological condition as shown by uniformly slow or marked reduction in rate of growth, lack of response to environmental stimuli, or the production of certain sugars in the phloem. Previous infestations may add to that attractiveness because of the accompanying phloem fermentation. Many susceptible trees are infested by certain species of insects for some time before final infestation and death occur. If these causes of attractiveness could be correlated with external characteristics, it would then be possible to classify the susceptibility of trees and of stands on the basis of such characteristics.

Tree Susceptibility and Risk Classifications

In order to have a practical basis for judging the relative susceptibility to bark beetle attack of different tree types, Keen (*5*) set up a 16-group classification based on the two variables of age and crown vigor. This classification was developed as an expansion of Dunning's 7 tree classes after a study had indicated that some of Dunning's classes were too broad to give a close recognition of different degrees of tree susceptibility. Four ages, viz., young, immature, mature, and overmature, were recognized; and crowns were divided, according to relative size and position, essentially in accordance with the well-established divisions of dominant, codominant, intermediate, and suppressed, in so far as such crown divisions apply in open-grown ponderosa pine stands. As in Dunning's system, this expanded classification was essentially a grouping of tree types on the basis of their silvical characteristics.

In classifying ponderosa pine stands according to this system, records have repeatedly shown that trees killed by insects are largely those of poorest thrift (crown classes *C* and *D*), and more frequently those in the older age classes 3 and 4. From 7 years' sample-plot records, involving some 38,880 beetle-killed trees, mortality rates have been determined for each tree class. These show the relative susceptibility and give a preliminary estimate of the actuarial risk of each of the 16 tree classes. These rates apply primarily to virgin stands, and somewhat different rates may be expected in reserve stands left after different degrees of cutting in forests placed under management.

This classification makes possible the recognition of the broad silvical tree types representing the greatest susceptibility to bark beetle attack so that the risk of mortality from these insects may be taken into consideration by foresters in working out management plans for ponderosa pine stands.

The classification simply groups ponderosa pines into easily recognizable tree classes. It does not set up or imply a rule for timber marking. While it can be, and is now being, used by foresters as a convenient tool for this purpose, marking rules must be based primarily upon the objectives of timber management, which vary between different forest properties.

While this tree clasification indicates in a general way which types of trees in a virgin stand are most susceptible to bark beetle attack, and therefore the kind of tree representing the highest risk of loss over a long period of years, it does not show which individual trees are likely to be killed within any short period of time. In fact, a considerable percentage of the volume killed each year may be in classes of intermediate risk, and some loss may be expected even in resistant classes.

The work of the Berkeley laboratory, described by Salman and Bongberg (*10*) carries this work a step further in an effort to obtain a closer recognition of the characteristics indicative of immediate high risk. Following the leads furnished by the studies on attraction and on progression of insect attack in trees which ultimately succumbed to beetle attack, these studies seek a highly critical evaluation of current health symptoms of individual trees. Long-term silvicultural objectives are not involved. The primary consideration is to provide criteria for use in a rapid cleanup of currently susceptible individuals over large areas in an attempt to reduce the losses of the next few years by the use of what is considered today to be an extremely light cut. Its application would be a sanitation, not a silvicultural, measure. It is designed to precede, not to be a part of, long-term silvicultural practices and cutting cycles. It can be used as a first step in a more intensive management of virgin ponderosa pine stands in the eastside region.

A comparison of the tree classification defined by Keen and the risk ratings proposed by Salman and Bongberg, shows that both these systems are concerned with the relative susceptibilities of ponderosa pine trees to insect attacks. The first considers the types of trees showing greatest average susceptibility to bark beetle attack, the second defines the characteristics of individual trees showing the highest current risk. Both systems aim toward the conversion of susceptible trees into merchantable values before they have become degraded or destroyed by insect attack, bluestain, and rots.

The tree classification is primarily silvicultural in character and operation, with emphasis on the entomological phases of the silvicultural problems. It is designed for long-term protection through the use of lighter cuts than have heretofore been used. The use of the risk ratings is primarily for sanitation or salvage operations designed to produce the minimum volume of cut and secure even greater mobility of operation and rapid coverage of area.

The criteria employed in determining susceptible classes of trees and individuals of high risk are necessarily somewhat different. The tree classification places emphasis on age and crown vigor in determining susceptible classes. The criteria of age are bark characters, shape of top, branch form, and diameter. The criteria of crown vigor are crown length, width, and density, conformation including branch spacing, position in the forest canopy, and the age-diameter ratio. In rating the risk the criteria used are those of needle length and color, needle complement, condition of twigs and branches, and evidence of infestations as indicated by top-killing or localized thinning or weakening in the middle and upper portions of the crown. Age, crown configuration, shape, or size are not involved in risk ratings, but the general vigor of the crown is considered under both systems.

Application of Results

The studies on tree selection by insects have been carried on for the purpose of meeting the practical problem, facing the timber owner, the manager, and the pine-utilization industry, of how to control or stop insect losses in ponderosa pine forests of the Pacific Coast States. While these studies are incomplete and need further testing, they have already demonstrated how the situation may be helped and give hope that, in situations where they can be applied, successful pine beetle control may be accomplished through forest management and utilization methods. In fact, tree selection by insects seems to be the natural silvicultural system in these ponderosa pine stands. The present system of classifying trees by susceptible types and risk ratings interprets this insect selection and shows how man may go in ahead of outbreaks and harvest a large part of the potential loss.

From the standpoint of complete salvage, the most desirable practice would be to cover all hazardous forest areas each year and take out all actual or potential "bug" trees of that year. Under conditions prevailing in recent years, this salvage material would have been sufficient to meet over half the total log requirements of all pine mills in the region. Except on accessible working areas, however, such complete salvage would be impractical because of the large area to be covered, and would not prevent the lowering of values caused by bluestaining fungi which are associated with pine beetle infestations.

The alternative would be to make a light sanitation-salvage cut on a short cutting-cycle basis, taking out individual trees of highest risk as indicated by risk-rating characteristics. This method makes possible the utilization of a high percentage of the potential loss, and the relatively low volume cut per acre allows treatment of a large acreage. In tests of the salvage-logging operation the removal of about 16 percent of the stand has resulted in a reduction of losses by more than 70 percent for a period of 3 years after treatment. While this method offers the best chance of obtaining a prompt reduction of losses without the necessity of removing a high percentage of the stand volume, accessibility of stands will limit its application. It is essentially a preliminary cutting to obtain prompt beetle control, and supplements, rather than replaces, the broader general principles to be applied in any long-term silvicultural or management plan.

Because of the rapidity with which individual tree-health conditions may change, any long-term plan of reducing insect losses and improving stand resistance necessarily must be based on a consideration of trees by groups or types rather than as individuals. The basic characters on which the bark beetle-susceptibility classification is founded are of a type which changes but slowly. The 16 classes give wide latitude in tree selection, and the information on mortality ratios for each tree class makes this classification particularly well suited for timber marking on a selective basis where consideration is to be given to the potential threat of insect damage over a long cutting cycle. Since a cutting by tree classes is less selective as to trees which may die in the near future than a cutting by individual risk rating, a higher volume has to be cut to obtain equal short term protection, and a smaller percentage of the total forest area can be covered in a given period of time. Thus for short term beetle control purposes, a cutting by risk characters is preferable, while for long term protection, including silvicultural and forest management considerations, tree classes offer the best guide.

Beetle control through tree selection and sanitation logging offers many advantages over the previous fell-peel-burn method of direct control. Results of tests so far show a greater reduction in subsequent losses than is usually obtained by the older method. Moreover, the recovery of timber values which would otherwise be lost may offset much of the cost of treatment and may even yield a profit. On the other hand, this method is limited in its application to commercial timber stands of fairly high value and that can be reached by logging operations at a reasonable cost. This method is not appropriate for beetle control in parks, recreational areas, or inaccessible commercial forest areas in rough terrain. For such situations as these, fell-peel-burn or other direct control methods still offer the only practical measures that can be used.

What method of insect control to apply, and when and where to apply it, will depend on field conditions, difficulties in application, and economic considerations as well as entomological factors. Each individual property and situation will have to be considered from these various angles and a method of control selected which will meet the specific forestry needs or those of the timber owner.

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