THE INSECT FACTOR IN PONDEROSA PINE MANAGEMENT IN REGION 6 AND REGION 5

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Figure I. Large ponderosa pine killed by Dendroctonus brevicomus Lec. Proper forest management technique should tend to avoid losses of this kind. Photo by J. Callaghan, April, 1935.

INTRODUCTION

In the three Pacific Coast States that form the major portions of Region 6 and Region 5, the settler of earlier days found some of the nation's mightiest stands of timber. In the eastern half of these states of the last frontier, the majestic pine forests ruled supreme, as they had ruled for centuries. It is not for me to comment on the past exploitation of this mighty stand of pine through fraud and wasteful practice. These are things of years gone by. The time has gone as have large areas of the trees. The time will never return, and the second crop of trees will perhaps never equal that of the virgin stand. But there still is the future. We still have large areas of uncut virgin pine and new areas of second growth. These areas demand protection. As foresters we must see that they get it. Protection doesn't mean simply protection from fire, from disease, from windfall or insects. It doesn't mean protection from wasteful harvesting technique or from erosion. It must evolve itself into a well knit program of all of these things and all others necessary to grow and harvest timber crops.

This paper deals in the main with the insect infestation problems common to the area, and how they may be solved in part for this stand. The application of various control measures considered in this paper are in no way to be considered as blanket coverage cure-alls for our insect problems in the ponderosa pine areas. They are merely indicative of what has been done to meet various problems of this field, and to show the present major trend of insect control, namely, the application of susceptibility ratings in the management of our pine forests.

The author is extremely grateful to the Bureau of Entomology, the United States Forest Service, the Forest Experiment Station, the Western Pine Association and others for data and criticisms cheerfully given in the composition of this thesis. I wish particularly to thank Dr. A. S. West and Mr. J. M. Whiteside.

THE INSECT FACTOR IN PONDEROSA PINE MANAGEMENT IN REGION 6 AND REGION 5

Approximately 38% of the total ponderosa pine stands of the United States are within the boundaries of Oregon and Washington. In 1932 Oregon had a stand of 79 billion board feet while Washington's total was 15 billion board feet. Present figures are unavailable but considering average growth and loss figures, Oregon has about 75 billion left and Washington has about 13 billion. Large portions of this area are classified as site III and IV with much of the timber being mature and overmature. (18)Conditions of this kind result in a general lack of thrift which in turn results in heavy losses due to fire, fungi, insects and windfall, thus presenting a startling set of timber loss figures. Study of these losses shows a wide intangible field composed of many phases, the most important, considering actual losses, being the insect phase. Insect losses are hardly to be considered as something of recent advent. We always have had insects in our forests and, unquestionably, we always will have. Fossil imprints show that we had forest insects centuries ago. The forests would be neither complete nor natural without its insect life, many of the insects being very beneficial as predators, parasites, and slash disposers.

It is said, particularly in Region 6 and northern California ponderosa pine forests, that bark-beetles seem to be on the increase. This is probably rather erratic.

Ponderosa pine has in all probability had insect infestations years before white people set foot in this area. Studies by Dr. A. S. West(29) and other entomologists show conclusively that small flecks throughout the wood of ponderosa pine are a result of the past work of different species of Dendroctonus, Melanophila and other genera. With the rapid harvesting of this timber, the work of these insects becomes more evident as the remaining stands become more scattered. Along with timber cutting, we cleared areas for roads, logging spurs, and other economic developments; fire ate its way into stands, helping disease, windfall, etc, to deplete the once mighty forest. The current dry cycle has materially aided various tree killing insects by producing a general lack of vigor in the stands. All in all, however, the insect population fluctuates with conditions and will tend to hold to a rather steady level. (See figures 2 and 6)Studies by Dr. K. A. Salman(26) on Dendroctonus brevicomus Lec. show that the number of larvae per square foot tend to show a fair balance:

Year	Number of Larvae per Square Foot
1926	53
1930	90
1931	130
1935	60
1936	60 (approx.)

Chamberlin says: "The average board foot loss in ponderosa pine from insect activity is no greater now than the same average loss for equal climatic conditions of years ago. Hence the problem has not changed greatly but has become decidedly more noticeable, and those interested have been endeavoring to formulate plans to cut down the losses. For this reason it is necessary that the forester have a proper conception of the subject in its technical and economic phases, and that he appreciate the importance of the activity of various species that he may have to deal with to bring his crop to maturity"(5).

To determine methods of checking insect losses, the entomologist must make a thorough study of the insect and its habits, then plan methods of control. To this end many entomologists have put in years of research in the ponderosa pine belts of the west.

Ponderosa pine, like white oak, has a myriad of insect enemies. The more important enemies belong to the family Scolytideae, characterized by Chamberlin as the most important group of forest insects in the world. They are found in all stages of tree development from seedling to maturity. They are found in roots, stem, limbs, bark, needles and cones.

Control measures in Region 6 and northern California have dealt mostly with the following insects:

I: Dendroctonus brevicomus Lec. (Western pine beetle)

This beetle is nominated by most authors as the most destructive pest to pines in the west and is responsible for tremendous annual losses. Ponderosa pine is the chief host of this beetle who is easily identified by the winding subtransverse egg galleries so common to ponderosa pine throughout almost its entire range. The flight begins in June, the adults boring into the cambium of the tree they select and starting their egg galleries. Pitch tubes are not uncommon at points of entry. Eggs are isolated and larval galleries penetrate outward into the inner bark. Pupation takes place near the bark surface, the new adults emerging by boring directly out through the bark. The parent adults soon die. According to Chamberlin (6) one to three generations are produced each year depending on the latitude and altitude. The species is distributed throughout the range of its host trees in California northward to British Columbia and eastward as far as Montana.

II: Dendroctonus monticola Hopk. (Mountain pine beetle)

This insect is slightly larger than the western pine beetle and is black in color. The galleries of the mountain pine beetle differ from the above in that they go rather straight up the tree, at times winding slightly. The egg cells extend at right angles from the main gallery and the larval mines are exposed upon barking. New adults emerge in June and there is generally only one brood per year. The main hosts of the insect are sugar pine and lodgepole pine, but ponderosa pine is often heavily hit, mostly in conjunction with the western pine beetle. The range is similar to that of D. brevicomus.

III: Ips sp. (Engraver beetles)

The engraver beetles of the genus Ips are often very destructive to second growth pine and to the tops of mature trees. They probably rank next to the genus Dendroctonus in order of destructiveness to California pines according to Keen(14).

Keen says: "Their normal habit is to feed on the cambium of recently felled pines, and they breed very readily and in large numbers in such materials as windfalls, snow breaks, logging or road slash. Having increased their progeny in fallen logs and slash, they often emerge in great numbers and kill ajacent groups of young pines and the tops of mature trees. Usually, however, such epidemics of killing living trees are of short duration and after one season the beetles return to their diet of freshly felled logs. Some of the species are only of secondary importance, and are rarely found attacking living healthy trees."

Their habits of boring into the cambium are similar to the Dendroctonus beetles, the main difference being the lack of frass in the egg galleries. The beetles have a pronounced posterior cavity lined on the sides by spines. According to Keen(6) from two to five generations develop during the summer depending on altitude, latitude and species. The more important species for this region are Ips oregoni, (Eich.), Ips emarginatus (Lec.), and Ips confusus (Lec.). All are generally distributed throughout the western pine forests.

IV: (Flat Headed Borers) Family Buprestidae.

These insects are known as the metallic borers and constitute a very destructive group of forest insects. The two most important species of pine enenies belong to the genus Melanophila and are quite capable of killing healthy trees by mining under the bark. They differ greatly from the Dendroctonus and Ips beetles in that they lay their eggs on the surface of the bark. The larvae when hatched burrow into the cambium making long flat winding mines packed with frass in arc-like layers. The two species commanding the most attention at present are Melanophila gentilis Lec., and Melanophila californica Van Dyke. These two species will be considered fully in another part of this paper.

V: Coloradia pandora Blake (Pandora moth)

Keen says: (14)"Periodically the caterpillars of this moth completely defoliate the western yellow pine and Jeffrey pine over large areas. All of the needles are eaten with the exception of the terminal buds. The result is a serious checking of the tree's growth and a lowering of its vitality so that it becomes an easy prey for the bark-beetles. Since the terminal buds are not eaten the trees usually recover from the defoliation if not attacked by other insects.

During the period of feeding, large greenish spiny caterpillars will be found singly or in groups feeding upon the needles. These caterpillars reach a length of from two and one-half to three inches when full grown.

The adults are large gray-brown moths with a wing expanse of from three to four inches and heavy cylindrical bodies an inch or more in length.

Flights occur in July and August of alternate years. Eggs are laid in clusters on the trunks and limbs of pines. The larvae upon hatching live on the needles, hibernate there the first winter, feed on the needles the second summer, and descend to the ground the second winter to pupate. The larvae and pupae are prized as a food by the Pai-Ute and Klamath Indians. The pupae emerge in July and August as full grown moths. Heavy epidemics occur only at intervals of about thirty years."

Drain Figures for R-6:

Prior to 1929 very meager records of losses due to insects, fungi, and windfall were kept in this region. We find control work beginning at this time in southern Oregon and northern California, with estimates of losses indicating the serious nature of these depradations. In 1929 the Bureau of Entomology at Portland, Oregon, began to make estimates of insect losses for the region as a whole. This study has been carried up to the present and the totals form some rather alarming figures.

In Figure 2 (3)we find the board foot loss per acre per year from 1921 to 1936. As may be expected, epidemic years show huge losses while the endemic years tend to hold to a fluctuating balance. These figures refer to insect losses alone. The average is slightly over 300 board feet per acre per year.

Figure 3 compares the total ponderosa pine drain in R-6 with the total growth for the five year period 1931 through 1935. In this period we find cut leading the drain elements with a total of 4,600,000,000 board feet. This is closely followed by insect losses totaling 4,500,000,000 board feet. Far down the line we find windfall loss estimated at 1,000,000,000 board feet, and fire with a loss of 300,000,000 board feet. On the other side of the picture, growth appears rather weak with its total of 2,500,000,000 board feet. In all fairness it must be admitted that growth which represents .5% of the stand at present is lower than its usual 1% due to adverse weather conditions for the past several years.(34) This same dry cycle has helped to swell the total of the insect losses and to a less degree the fire loss. Therefore the estimates would seem a trifle high for losses and somewhat low for growth. For this period the growth percent is about .5% of the total stand and the drain represents slightly over 3% of the entire ponderosa pine stands of R-6.

Let us look back over these years shown on the charts.

Figure 2

INSECT LOSS IN R-6 PONDEROSA PINE

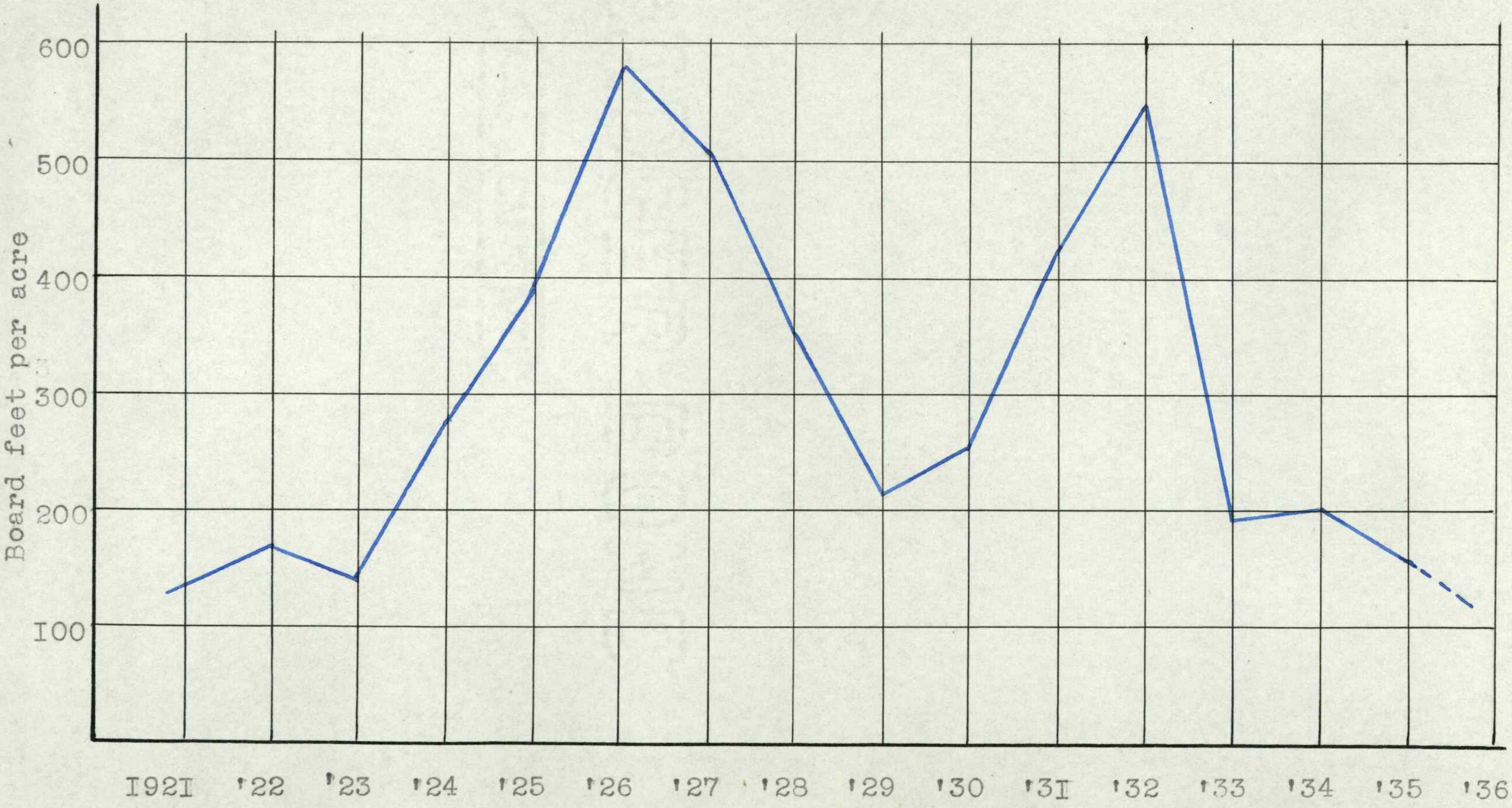


Figure 3
TOTAL DRAIN IN R-6 PONDEROSA PINE
Compared with
GROWTH
1931-1935

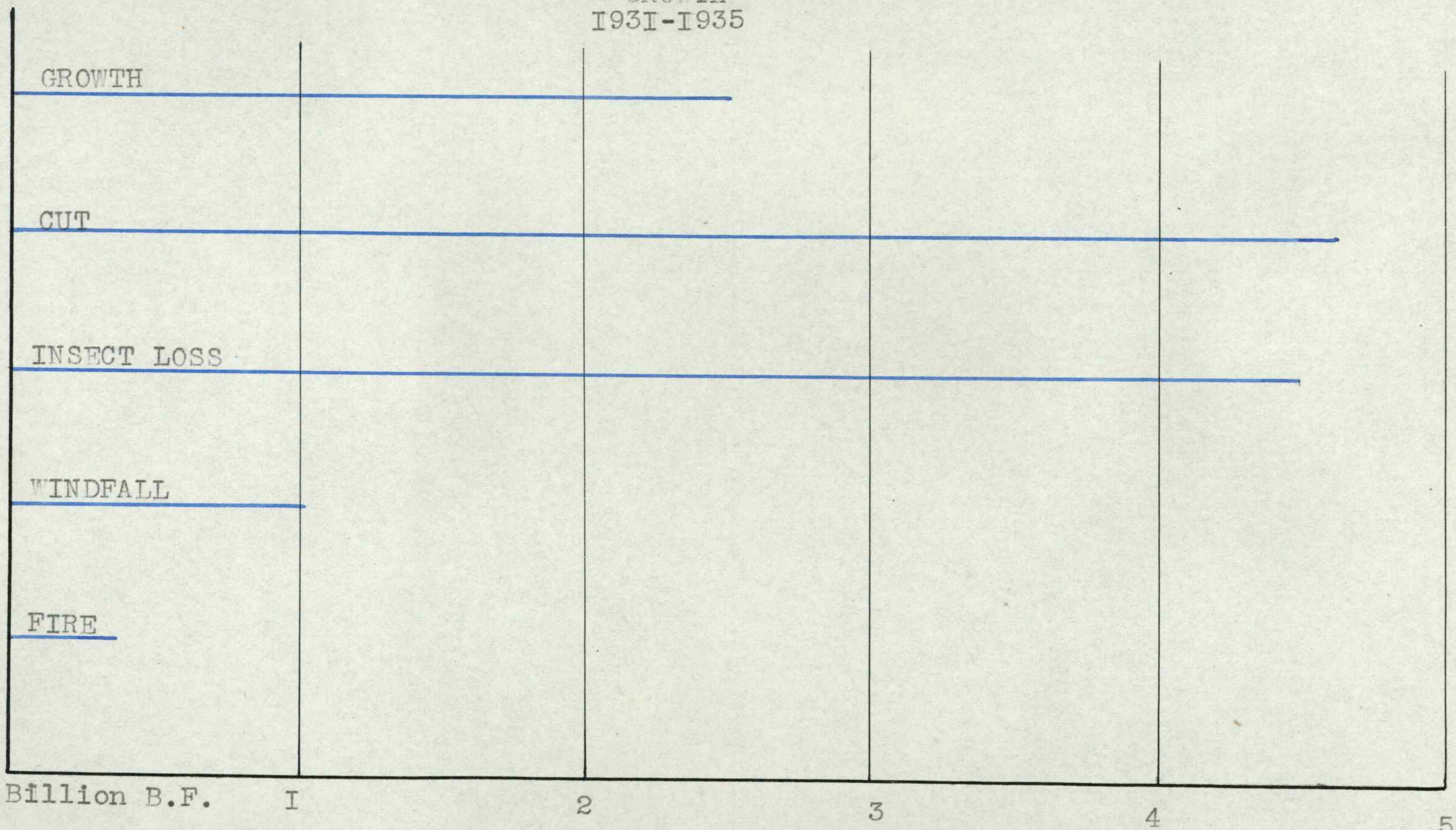
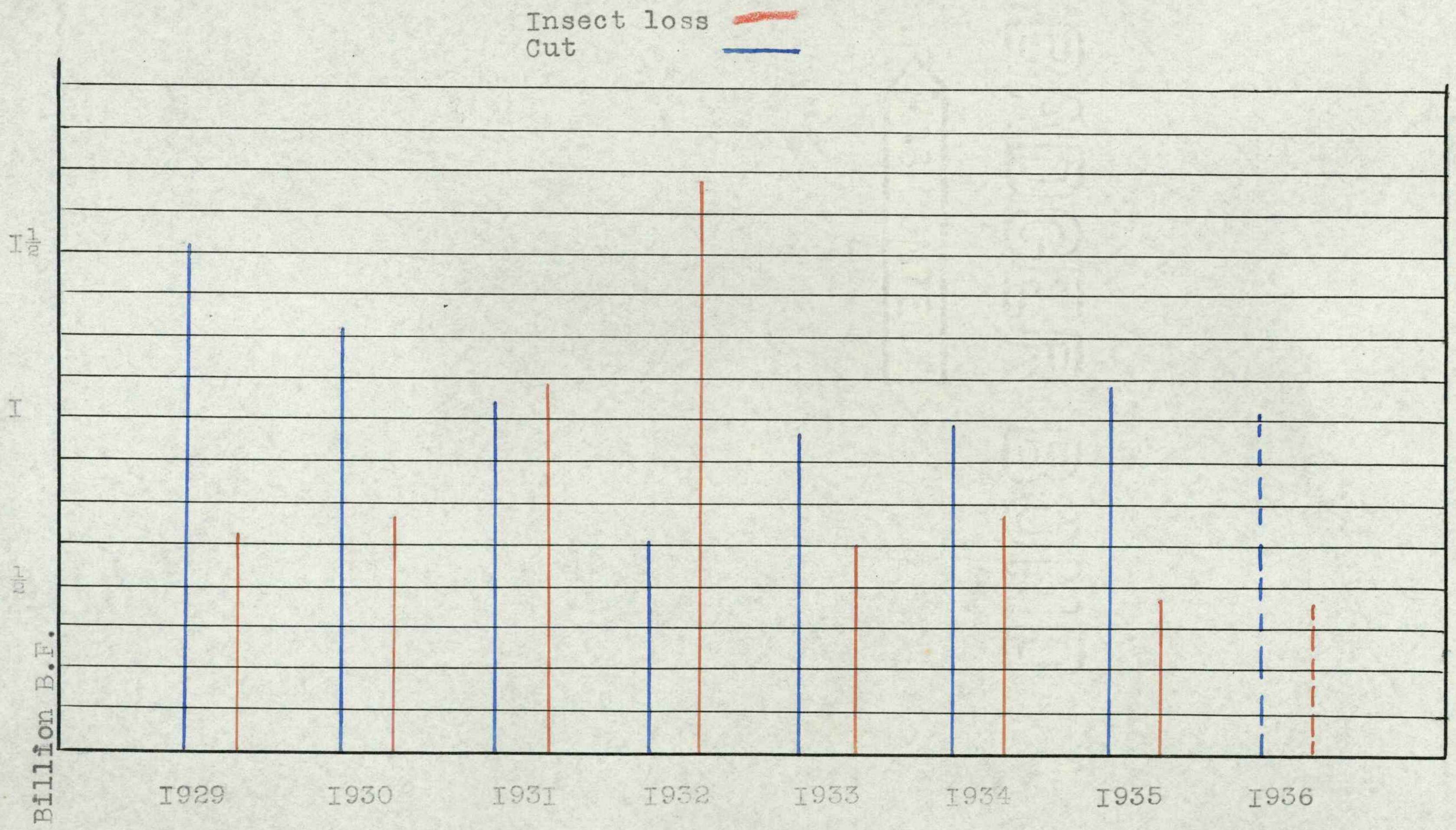


Figure 4

TOTAL CUT IN R-6 PONDEROSA PINE
Compared with
TOTAL INSECT LOSS



Every newspaper in the land will show glaring headlines telling of the toll of forest fires each summer. Forest fires were the subjects of conversation from the street corners to the Congress. They blazed in their spectacular way throughout this five year period as they had before, completely overshadowing a few species of small harmless little insects. Insect losses will be found in very few news sheets of that era or others. These same losses were rarely discussed by people of our modern world. Why was this? Partly because conclusive figures were not available and partly because people do not notice things particularly unless they assume the spectacular aspect. The smoke in far away mountains, coupled with the newspapers, news reels, and radio, impress the public because they are able to visualize the losses that are occuring. The little pine beetle and his associates, depicted by Chamberlin(7) as "The Silent Army", continued in his modest way to kill fifteen times as much timber as fires had accounted for in this five year period. Unquestionably the current dry cycle has magnified these figures, but at the same time, they present totals that can not be denied much longer.

Forest protection is one of the greatest jobs of the modern forester and it should include ample protection for all of its ramifications. H. B. Pierson(24) expressed this thirteen years ago in the following far seeing lines:

"Looking into the future, I firmly believe that unlimited good will come from a closer association between men in varied lines interested in forest conservation. The problems are so tremendous and varied, so little is actually known it hardly seems as if we had any more than started in what is apparently the right way. However, I am firmly convinced that the control of forest insects is just as practical as the control of forest fires, and with the proper support the time is not far distant when the pioneer work of today will be superceded by the systematic prevention of future wide spread insect depredations; the secret of successful management of our forests of the future lies not in fire protection, in disease and insect eradication, in methods of cutting or planting, but in a combination of these factors in which each is given its just consideration."

Figure 4 is a graphic representation comparing fire and insect losses for the years 1929 through 1935 with the years 1936 and 1937 estimated from unpublished figures (34) and trends. The year 1932 goes down in history as the banner year for insect losses with a total of 1,707,000,000 board feet. The larval mortality for the sub-zero temperatures of the fore part of 1933 (15) procluded any recurrence of this vast total in the summer of 1933.

Drain Figures for Region 5:

In the California region we find a parallel relation of insect losses to those of R-6. Studies of a less intensive measure were carried on until 1931 when the work of surveying insect-caused losses in the ponderosa pine timber stands of this region was organized as a major project of the Berkeley Laboratory of the Bureau of Entomology and Plant Quarantine. This study was entitled "Regional Survey of Forest Infestations and Trends". The following figures and notes are excerpts from the results of this survey:

Quoting Salman: (27)

"The primary basis for estimates of insect-caused losses in infestations units, management units, sub-regions, or for the region as a whole, is secured by cruising losses on selected plots. Most of the plots are 320 acres in size. They have been selected to be representative of and to sample about 1,250,000 acres of the 6,818,000 acres of commercial pine type in this state. Reconaissance cruises and observations are used to extend the application of the sample to the timbered acreage. Interpretations of infestation trends are secured by studying the changes in the amount of loss, the characteristics of infestations, and the relative importance of insect species in the year-to-year record.

The records of a single year present the losses that result from the activities of all the insect species, from the interactions between the several species or from the action of environmental factors in determining the degree of success or failure of the broods."

Figure 6 presents the insect losses in California forests for the years 1925 through 1936. These figures including sugar pine, Jeffrey pine, and lodgepole pine may not be quite as accurate as the above figures for R-6, but inasmuch as ponderosa pine constitutes the major portion of the pine stands of R-5, the results will prove quite comparable.

In this report Salman(27) states:

"In 1928 Keen estimated that the average annual insect-caused loss in the pine stands of California was 500,000,000 board feet. Heavier than normal losses had been recorded for several years previous to 1928. Since that year abnormal environmental conditions and excessive insect activity has been the cause of maintaining the loss above average in every year except 1930."

It seems ironic to find that the insects have removed ten billion board feet of merchantable timber in the period 1925 to 1935 inclusive. For the same period only slightly over sixteen billion board feet made up the total cut, including the redwood cut.

Figure 7 compares the cut, kill, and fire losses for R-5 for the period 1930 through 1935. This, including 1932, finds the insect losses greatly above normal. Board foot

Figure 5. Windfall area on the Shasta National Forest, R-5. Taken on the Long Bell cutover land near Cougar Butte. Photo by K. A. Salman. Oct. 17, 1937

losses per acre compare rather favorably with those of R-6, particularly the east side ponderosa pine types of R-5.

Figures on windfall loss are unavailable for the California region, but there is a rather definite loss in local areas as may be seen by Figure 5.

What These Losses Have Meant:

In specific areas these losses are much more apparent to the average individual than they are in the pine regions of California, Oregon, and Washington as a whole. From recent mill scale studies, Ericson(11) indicates that ponderosa pine trees under a 20-22 inch d.b.h. class in most instances will not pay for their manufacturing costs. In conjunction with this, Craighead, Miller, Keen(8), and many other noted entomologists show conclusively that the western pine beetle shows a decided preference for the slow growing mature trees of the stand, except during epidemic conditions. With trees under twenty inches showing a minus value, and the trees of larger sizes apt to fall prey to the forest insects, the mill owner has his operating margin cut down to a certain extent. Obviously, all large trees aren't slow growing or decadent, and all small trees aren't fast growing and thrifty, but generally speaking, the insect factor, plus the negative value of small trees, will make the road of the pine manufacturer slightly uphill.

Another form of loss, quite apparent to individuals, is found in parks, resorts and recreational areas. The

Figure 6

ANNUAL LOSS FROM FOREST INSECTS

in

California

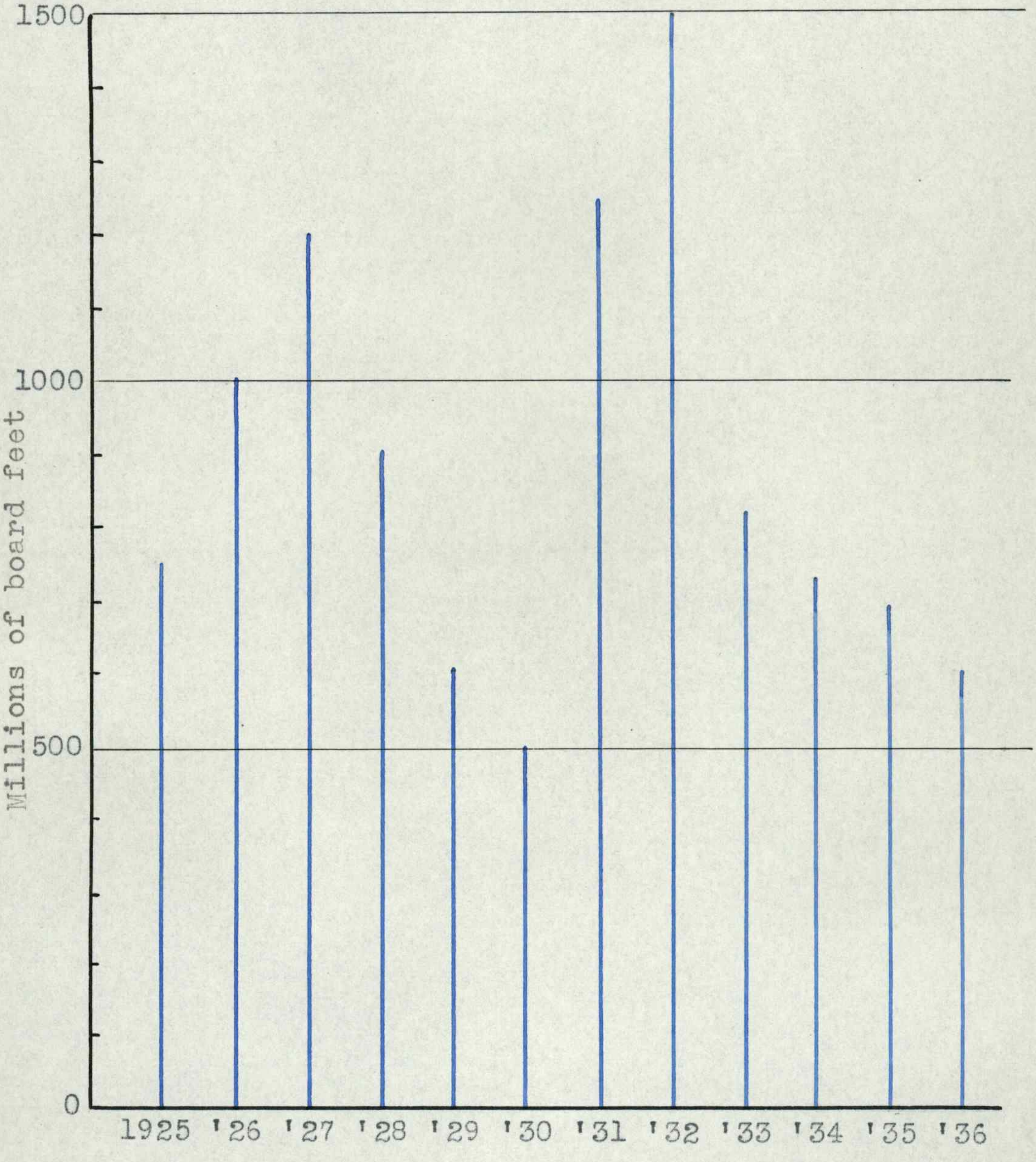
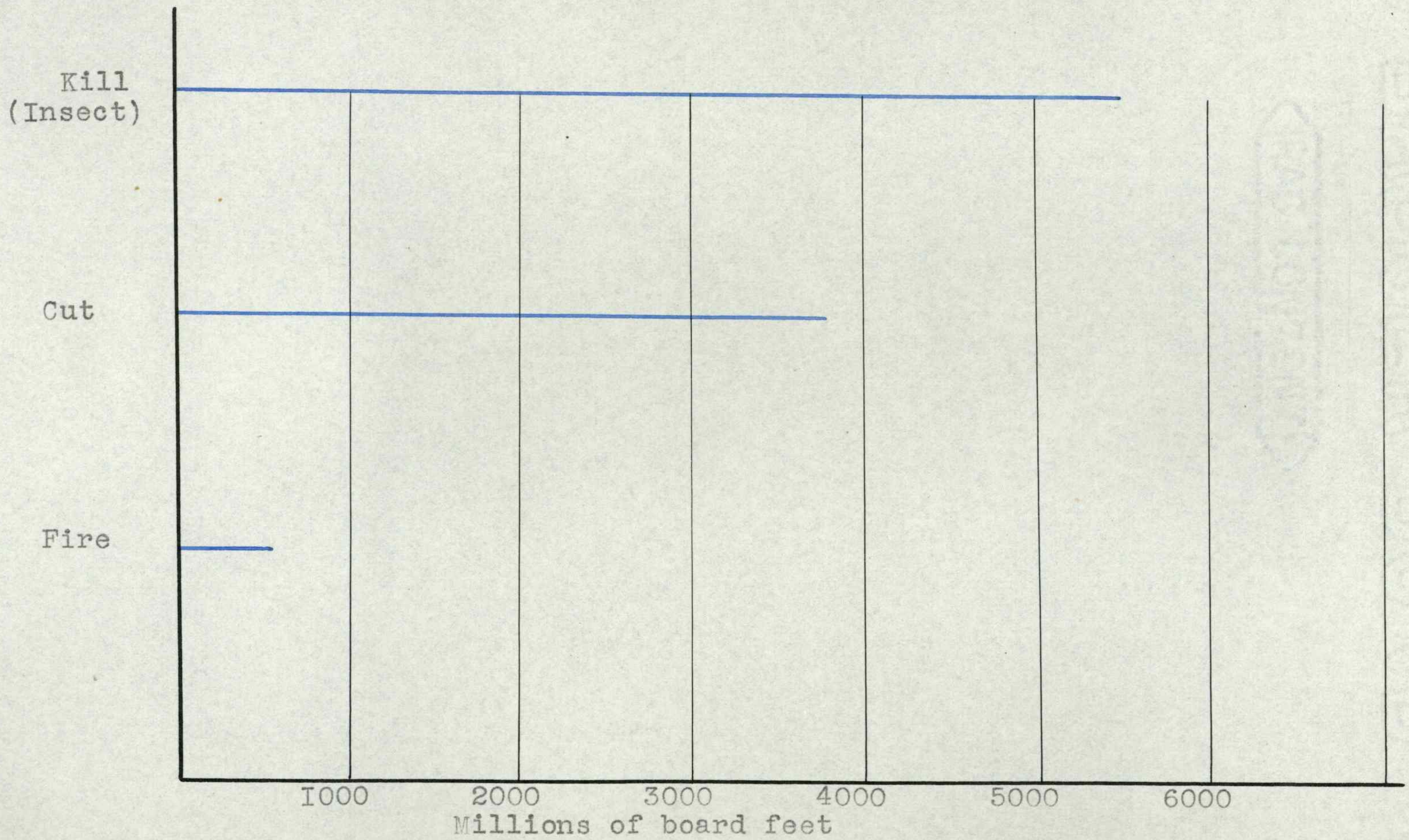


Figure 7

TOTAL DRAIN IN CALIFORNIA PINES
1930-1935 (incl.)



drawing attractions of places of this type are quickly and almost permanently ruined when the views are rendered unsightly by an insect infestation. Areas, like southern California, where trees are limited, find themselves at a definite disadvantage when insect depradations set in.

To the fire suppression departments of local and regional areas, the results of insect losses are perhaps more apparent than to any other single group of individuals. Anyone who has ever been connected with fire suppression in the ponderosa pine belt has had ample opportunity to see the havoc caused by snags. Fire trails are almost useless as long as these flaming monuments to the prowess of pine beetles are left standing. In the Long Bell and Shaw-Bertram stands of northern California we find some of the most hazardous fire danger areas of this region. One specific section has an estimated 95% kill resulting from the inroads of Dendroctonus and Melanophila beetles. It is difficult to visualize an area of this type without seeing it. Big trees and saplings alike are all in various stages of deterioration. Bark hangs loosely on many of the standing snags, while the ground is a maize of interlaced windfalls. Fires in areas of this type are virtually impossible to stop in the day time, and require large forces of men and equipment to corral them at night and hold them the ensuing days. To be sure, all areas are not like this, but a few of this type (see Fig. 19), interspersed with thousands of acres of green timber having varying numbers of snags, makes protection and suppression costs mount higher and higher throughout the years.

Using Keen's(27) low appearing estimate of an annual loss of 500,000,000 board feet in the California pine region and estimating a conservative 600,000,000 board feet annual loss for R-6 we may roughly compute the stumpage value monetary loss. T. J. Starker(28) gives an average stumpage value of three dollars per M for ponderosa pine. With an average annual loss of 1,100,000 M in the two regions we find a loss in stumpage value alone of $3,300,000 for California, Oregon and Washington ponderosa pine forests. The annual loss for the past few years will greatly exceed this due to the present dry cycle. Hence we find that there is a very definite problem to contend with.

This is not the total loss due to insect infestation. According to Craighead(8) more than a million dollars a year was spent up to 1930 in order to find means of controlling the depradations of the bark beetles. Naturally a great deal more has been spent since 1930. Another loss is tied in with fire suppression costs. It is impossible to know how much has been added to the control costs of forest fires due to the added hazard of beetle-killed snags.

Forest management has suffered through insect attacks. Working circles are layed out with cutting cycles and rotations computed. These figures, being based on average normal conditions, are of little value when it is wholly possible for insect attacks to remove from 15% to 50% of the stand within a five year period(8). Another disadvantage, that may hinder forest management, is found in conditions similar to one in the North Warner area of the Modoc National Forest in R-5. This area had a mixed cover composed of seventy-five year old ponderosa pine and white fir (Abies concolor). The character of the stand was changed to a pure stand of white fir by heavy concentrations of bark-beetles.

Such incidents as these will not completely stop the private forester from using some form of selective logging in the ponderosa pine in preference to clear cutting, but they present a definite obstacle for the forester of today to hurdle when he is endeavoring to sell the sustained yield principle to the private forester.

When we face losses, such as have been shown, in the forestry business, or any other business, we see the need of effective controls. These control method ideas have been the object of great research by various governmental departments and other individuals for many years. Research for control methods of ponderosa pine insect enemies has been particularly hampered by the lack of basic material from which to study, and by the lack of funds with which to continue studies. Individual insects must be studied endlessly, and their relations to forests and other insects worked out in minute detail. These studies must be correlated with others of a similar nature, inequalities erased and application made of the studies to prove their worth. Effective controls for one region oft times will not suffice in another. This is borne out by Beal(1). He says:

> "Our insect problems for this region are markedly different from those with which you are familiar with in Oregon. In the first place the Black Hills beetle (Dendroctonus ponderosae Hopk.), with which we are primarily concerned, shows absolutely no preference for mature or weakened trees as does the western pine beetle. The Black Hills beetle works in trees of all sizes and ages from 4" d.b.h. up to the largest trees in the stand. Under epidemic conditions it appears to prefer the more rapidly growing trees."

Hence Mr. Beal has a different problem than we do as he cannot use many of the premises for control methods as are indicated for the pine beetles of this region.

In a study of control of insect depradations we may classify control methods under three broad headings, namely, natural controls, direct controls and indirect controls.

Natural Controls:

From studies made in the Deschutes National Forest in 1925 and 1932-3, (15)coupled with studies made in the Modoc National Forest in 1932-33, (26)we find that low temperatures quite often may cause a desirable loss in the larvae of the Dendroctonus and other beetles. Studies from the Sierra Nevada regions(15) show some mortality at 0 degrees F., 60% mortality at -5 degrees, and practically no larval survival at -10 degrees F. Keen says: (15)"Broods obtained from regions where minimum winter temperatures are often below zero apparently have acquired a greater resistance than those from regions of a mild winter climate."

From studies made on the Ochoco National Forest in 1933, (15)figures are shown in the following chart: Temperatures ranged from 25 degrees F. to -26 degrees F.

Table 1:

Bark thickness inches	Subcortical Temp. degrees F.	Larvae Living	Larvae Dead	Mortality %
$\frac{1}{2}$	-17	26	69	72.4
$\frac{3}{4}$	-14	40	72	64.0
$\frac{3}{4}$	-11	24	30	55.5
1 1/8	- 5	71	68	48.9
$1\frac{3}{4}$	0	170	86	33.5

Studies of this nature show rather conclusively that sub-zero temperatures result in some mortality of the western pine beetle, and that air temperatures below -15 degrees F. result in an important reduction of the broods.

Precipitation tends to play an important part in the increase or decrease of insect populations. In years of heavy rainfall in May and June, the storms seriously hinder the spring flight of the western pine beetle. This heavy rainfall coupled with ample further precipitation throughout the year, will tend, after a period of years, to increase the vigor of the individual trees and of the entire stand. Except in epidemic years the western pine beetle shows a decided preference for weak and overmature trees, so a series of wet years, giving added vigor to the stand, should aid materially in reducing losses. On the other hand, prolonged drought will greatly increase average losses.

Results of windstorms, lightning storms and snow breaks may show a tendency to cut down insect losses according to Chamberlin(6) and Patterson(23). It seems that bark beetles entering into windfalls often come out in less numbers, due to the drying out of the host.

Predators play an important part in natural control. Among the insect predators we find members of the families Cleridae, Cucujidae, Ostomidae and Histeridae playing an important role, preying for the most part on the larvae of the principal bark beetle enemies of ponderosa pine.(5). Birds are important to a lesser extent. The woodpecker while eating numerous larvae points out many trees to the spotter and is the most important bird, perhaps, in a study of this kind. Reptiles, mammals and fish are of a lesser importance according to Chamberlin(5).

Among the parasitic aids to natural control we find members of the Hymenoptera and Diptera orders parasitizing the eggs, larvae and adults of various insect pests common to pines(32, 12). Chamberlin(5) says that we may be sure that parasitic bacteria, entomogenous fungi and nematodes exercise a vast influence over insect broods. This field is not very well advanced as yet but holds promise of being a large and important one to the forester and entomologist.

Direct Applied Controls:

Among other applied controls Chamberlin(5) mentions contact and stomach insecticides. According to Evenden(13) these methods show great possibilities in the control of certain insects, the hemlock looper being the best local example. However, it seems that for the present, few of the more common pine insects will be treated in this manner.

In the study of direct control methods used in ponderosa pine we will consider the bark and burn method, or the method of burning the entire tree which works nicely and saves time with small trees. This method in general will prove more satisfactory than others because in all probability we will be treating for western pine beetles with most trees, and in view of the fact that their larvae are in the inner bark, other methods might not prove too effective. Control methods of this type are preceded by a survey to determine the need of control measures. If conditions warrant this, camps are set up, spotters cover the area to be treated, and the treaters follow behind, falling, barking and burning. Follow up maintenance should be practiced.

The cost of this kind of control seems rather prohibitive. Keen(14) says that it costs $4.50 per M for the treating of the timber and 35¢ an acre for the ground covered. These figures are based on an average of 60 trees per section.

The effects of one season's control work are temporary and cannot be depended upon to hold the infestation down

Figure 9: Large ponderosa pine badly infested with D. brevicomus Lec. Note heavily blue stained areas. Photo by J. Callaghan.
April, 1935

for more than one to three years after the work is completed unless natural control factors become operative(14).

According to Craighead(8) only the following should be classified as areas where control will be practiced:

1. Parks and recreational areas of high value.
2. a- Small well isolated areas where timber is of high value, and the entire job can be gone over in one season.
   b- Large areas of partial isolation where the entire area can be treated supplementary to logging operations.

Among other things to consider in determining the need of control measures, according to Keen(14), is that we must be sure that we know what is causing the mortality of the trees. Is it mainly insects, or are fire, drought, and disease the primary causes of death? If bark beetles are the primary cause, is it normal or epidemic? We cannot hope to show very great results in treating normal endemic conditions. Is the timber worth the cost of treatment? Where timber values have been high the amount of timber worth saving has more than offset the cost of the work.

Another form of direct control that has been in and out of the limelight for many years and is coming back into an important position at the present is the injection of chemicals into the sap stream of the tree to kill insects and to preserve the timber until it can be cut and milled. Experiments by Craighead and St. George(9) and by Wilford(35), produce interesting problematical results. Craighead says:

> "Bark beetles introduce blue stain when they attack a tree (see Figure 9). Blue stain development varies greatly depending upon the species of the bark beetle, the host tree, the temperature and moisture conditions within the tree.....The control of bark beetles costs from one to twenty dollars per tree..... Copper sulphate is the most effective poison tested to date."

Wilford's tests(35) of the summer of 1937 on ponderosa pine will be checked closely this summer by West, who maintains that the upward progress of the solution will be halted by the galleries of the incipient larval stage of Melanophila californica Van Dyke(32).

Further tests of toxic oils in the treatment of infested bark, a method developed at the Berkeley Station (19), may bring forth still another method of direct control.

Indirect Control:

In the consideration of indirect control we will be dealing with ideas that can hardly be considered as new. It merely deals with phases of silviculture and management. Selective logging, forest sanitation, and a definite correlation between other types of losses with insect losses is the key to the entire problem of indirect control of insect infestations.

Let us consider selective logging as correlated with sanitation and insect loss. Obviously, in normal times, the pine beetle will select the slow growing over-mature trees, or the ones that have been injured mechanically or by fire and disease. If the operator would cut these trees before the beetles had the opportunity to kill them, he could turn a sure loss into a profit. The idea is not new. History tells us that the timber operator has always taken the largest trees first, these being for the most part the older more decadent individuals in this region. Now we are perhaps beginning to find a reason for this procedure. These trees are not putting on a great deal of growth, and each year they will become more susceptible to insect and disease losses.

Ericson(11), after an extensive study in the pine regions of eastern Oregon, brings out the following points: Trees below a 20-22 inch d.b.h. will produce a negative value....A 40% cut on a short cutting cycle was recommended for this particular region (near Burns, Oregon), and the operator in question said that in the future he could not operate successfully unless this same general plan was kept in effect.... This 40% cut is not to be considered a standard because different forest structures will indicate different cutting percentages.... The cut may run as high as 60% for the first cut on some areas.

Similar experiments on the Black Mountain Experimental Forest in R-5 produced similar results(31).

We find definite advantages in this method of taking from 40% to 60% of the stand and cutting on short cycles. The operator may cover his area in a much less time and at closer intervals. Susceptible trees are milled and quite often trees that have bark beetles in them may be milled at a profit. This is a method of insect control in itself, particularly if the infested bark is disposed of. Hence, the operator will be doing control work, something that he could not afford to do in a direct control project, and at the same time he will be running a profitable business.

With this method of cutting we improve the vigor of the stand and its general appearance by the removal of lightning scarred, cat-faced veterans and the poorly formed trees that probably would not recover greatly if released.

In the days gone by selective logging was frowned upon rather universally because of the fear of increased logging costs and less profit. With the advent of cat skidding and truck logging, particularly well adapted to the open pine forests, the possibility of getting logs to the mill cheaply on a selective logging basis became a reality. Miller(21) says that truck logging is in its infancy while the railroad has reached closely to its peak of effeciency. With the coming prominence of the bulldozer, we find road building becoming much cheaper each year. Dirt can be moved for eleven cents per yard now as compared with forty-five cents per yard twenty years ago(21). Once built, these roads can rapidly be put into shape for ensuing years. The Forest Service is helping the transportation problem with the myriad of roads constructed through the E. C. W. programs. The problem of slash seems to be taken care of according to Ericson(11) and Crawford(10). It will be left in place except for fire breaks and areas of high hazard. This is a two-fold aid to the operator. It lessens his costs of slash disposal and cuts down the possibility of insect concentration due to the large areas of slash left in clear cutting. Studies by J. E. Patterson(23) in connection with slash and insects along the Green Spring Highway construction job, show that perhaps the only bad effect of large areas of slash was the concentration of insects during the period when the slash was green (97% of the trees were attacked immediately after the trees were fallen). The mortality of larvae was rather high, and the concentration of future losses was short-lived. Studies by Chamberlin(5) bear this out.

In cutting on a selective basis we will be cutting on a form of a pathological rotation. This is definitely a cultural aid to the stand and should materially cut down losses directly or indirectly due to such diseases as Polyporus anceps Pk. and Polyporus ellisianus (Murr.) Long.

Fire bears a definite relation to insect losses and indicates strict fire control measures. This is perhaps best expressed by Patterson and Miller's(20) statement:

"Forest fires of sufficient severity to scorch the bark, cambium and foliage of ponderosa pine produce certain types of injury which makes certain trees especially attractive to the western pine beetle.

Many trees which have been only moderately injured by the fire and are apparently capable of recovering are attacked and killed by beetles after fires of this character.

The attraction of fire injured trees often causes a concentration of beetles within a burned area which lasts for one or two seasons after the fire. This attraction may extend two or three miles from the burn.

The concentration of these beetles within the burn does not develop into an epidemic condition. The loss from bark beetles in trees not injured by the fire is not materially increased by the concentration.

Forest fires do not harm the beetles greatly unless they burn the bark entirely off the tree.

Fire injured trees do not always afford favorable breeding conditions for new broods. Where trees have been defoliated by fire, an abnormally moist condition of the inner bark may follow which results in an abnormally high mortality of the broods in early larval stages. Conditions have been noticed where this might even serve as a control.

The principle role of the bark beetle in connection with forest fires is in the added destruction by the insects of moderately fire-injured trees, which otherwise would have survived.

Thus bark beetles supplement and increase the timber losses initiated by forest fires, while fires have but little influence in permanently increasing the losses caused by bark beetles."

With the advent of new fast fire fighting equipment, a multiplicity of roads to choose from, other roads to use as fire breaks, and a definite lack of acres of slash and snags, fire losses should materially decrease in areas where selective logging as indicated by Ericson and others is practiced.

From an aesthetic point of view our forests will be vastly improved by leaving a residual stand. The former devastated areas would be replaced by green forests, young and healthy trees growing better than in years past due to release.

All of this and the operator will still be making money. It will tend toward smaller operations. The little fellow who could not afford to put in miles of expensive railroad, buy heavy skidding equipment and put in large mills, now has a chance. He won't have to cut out because of excessively high overhead costs, and he will be cutting down his fire risks, disease and insect losses.

A final advantage to this selective logging system, with its many roads and flexible equipment, is found in the salvaging value of such a setup. We are bound to have bad fires and we are bound to have insect epidemics and windfall losses at times. The finest of management systems cannot prevent these sporadic outbreaks. With our full coverage of the area, and many smaller mills, the ultimate loss from disturbances of this type may be cut to a minimum.

From a study of the Northwest Forest Experiment Station(22) we find the following statements bearing out the above premises:

"The irregular virgin ponderosa pine forests in Oregon and Washington are silviculturally neglected and unmanaged. Partial cutting converts them into productive forest stands. Light and frequent cuttings are desirable since these help to maintain forest conditions, assist in building up the soil fertility, eliminate or retard the growth of shrubby vegetation, surplus reproduction and grass. The gradual removal of timber helps to develop windfirm trees and also permits corrections and modifications not possible under heavy cutting, and thus gives rather complete control over the composition and character of the forest.

The removal of the overmature elements of the stand (mostly the high mortality trees) converts the stationary forest to a growing forest. If only the trees likely to die before the next cutting were removed the gross growth of the stand would be realized as the net growth.

It is sound policy for both a public and a private forest owner to liquidate the low earning trees and to reserve for volume and/or value increment the high earning trees.

The shorter the cutting cycle the better the chances for salvaging, before deterioration, windfall and insect killed trees in the course of the regular periodic cutting.

Assuming that a light cut should be made, for example 40% with an assumed return cut in thirty years (the exact percentage depending on circumstances and the character of the stand) the following considerations should control the selection of the trees to be cut:

(a) Cut all positive value trees that will not survive until the next cut.

(b) Cut the trees that show a positive conversion value above the average of the whole stand but a low value increment; these are ordinarily the oldest and largest diameter classes, of slow growth and high mortality probability.

(c) Cut some of the low value increment trees whose conversion value is below the average of the whole stand as a measure of stand betterment."

Thus we have narrowed our field down to a rather fine point. If we cut the susceptible trees before they are attacked by insects we will be conforming to silvicultural, practical management rules of selective logging, and at the same time, converting at least a part of the annual $3,300,000 loss in stumpage to a profit to the land owner and operator. Hence our problem is that of determining the susceptible tree before it falls before the inroads of forest insects. It has been approached in two main manners in both R-5 and R-6. These are based on classifications of individual susceptible trees and classifications of specific areas in regards to susceptibility.

<u>Susceptibility Classifications of Individual Trees</u>:

The first important classification for ponderosa pine was made in 1928 by Duncan Dunning. Apparently the object of this classification as originated was to class trees according to their seed producing ability and other silvical considerations(33). Though not planned specifically as a standard of rating trees for susceptibility to certain insects, this classification has been so used and is the basis for Keen's and other ratings. This classification is based on age, crown dominance, crown size and general vigor. See Figure 10 and Table II for the chief characteristics of this classification.

From Meyer(18) we find a practical application of Dunning's classification in relation to insect control and how this may be applied to selective logging. Quoting Meyer:

"The practice of leaving dominant trees uncut, with a supplement of codominants should do much towards immunizing a selectively cut stand to insect attack. A reserved stand composed chiefly of dominants with scattered codominants should suffer only one-third to one-half the mortality of a reserve stand in which the tree classes are represented in the same proportion as in the virgin stand. On the other hand, a stand that is stripped of its best timber, only the smaller intermediate and suppressed trees being left, may suffer up to eight times as much mortality as the wisely cut stand. All dominant full-crowned trees whether of class 1, 3, or 5 are well on the safe side, Class 1, under 75 years of age, being the best risk. Intermediate trees with long thin crowns in classes 2-5 are the highest in mortality.

Trees with 85% to 95% crown length make the best diameter growth and decrease down to 65% where the diminution becomes very pronounced... Do not cut trees with crowns of over 65%."

Next in line of prominent tree classifications is Keen's. About his own classification Keen(16) says:

"The following tree classification was developed for the purpose of determining, in the ponderosa pine forests of northeastern California, Oregon and Washington, the relative susceptibility of various tree classes to western pine beetle attack. Since its development, the classification has been found useful also in logging and silvicultural studies and in marking practice."

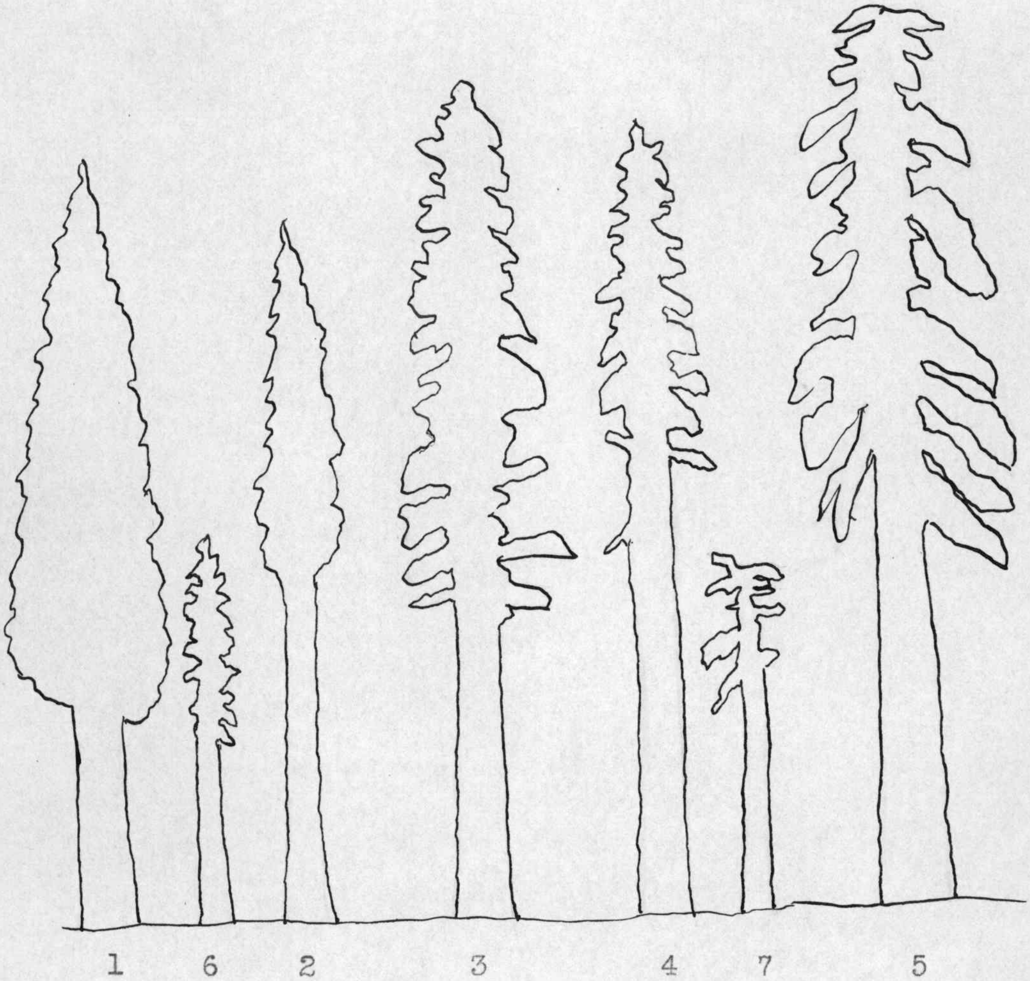


Figure 10: The seven tree classes of ponderosa pine recognized by Dunning. (Copy from U. S. F. S. photo.)

Table II

THE CHIEF CHARACTERISTICS OF DUNNING'S CLASSES FOR PONDEROSA PINE

Tree Class	Age Class	Crown Dominance	Crown Length	Crown Width	Form of Top	Vigor
I	Young or thrifty mature	Isolated or dominant	65% or more	Average or wider	Pointed	Good
2	Young or thrifty mature	Usually codominant	Less than 65%	Average or narrower	Pointed	Good
3	Mature	Isolated or dominant	65% or less	Average or wider	Round	Moderate
4	Mature	Usually codominant	Less than 65%	Average or narrower	Round	Moderate to poor
5	Overmature	Isolated or dominant	Any size	Any size	Flat	Poor
6	Young or Thrifty mature	Intermediate or suppressed	Any size Usually small	------	Round or pointed	Moderate or poor
7	Mature or overmature	Intermediate or suppressed	Any size usually small	-------	Flat	Poor

This classification is an outgrowth of Dunning's which, as all classifications do, proved to be inadequate in coverage, as there was much overlapping needed to classify some trees. This classification embraces sixteen classes based on age and crown vigor.

Keen(16) lists the age and crown vigor classes as follows:

AGE GROUPS:

1. YOUNG. Age: Usually less than 75 years. D. b. h.: rarely over 20 inches. Bark: Dark greyish-brown to black, deeply furrowed, with narrow ridges between the fissures. Tops: Usually pointed, with distinct nodes. Branches: Upturned and whorls.

2. IMMATURE. Age: Approximately 75 to 150 years. D. b. h.: Rarely over thirty inches. Bark: Dark reddish brown, with narrow, smooth plates between the fissures. Tops: Usually pointed, but with nodes indistinct. Branches: Mostly upturned and in whorls for the upper half of the crown.

3. MATURE. Age: Approximately 150 to 300 years. D. b. h.: Rarely over 40 inches. Bark: Light reddish brown with moderately large plates between the fissures. Tops: Pyramidal or rounded. Branches: Upturned near the top. Those of the middle crown horizontal, lower ones drooping; whorls incomplete.

4. OVERMATURE: Age: More than 300 years. D. b. h.: Usually of large diameter. Bark: Light yellow, the plates

usually very wide, long, and smooth. Tops: Usually flat making no further height growth. Branches: Mostly drooping, gnarled, or crooked.

VIGOR GROUPS:

A:-- Full, vigorous crowns, with a length of 55 percent or more of the total height, and of average width or wider; foliage usually dense; position of tree isolated or dominant (rarely codominant); diameters large for age.

B:-- Fair to moderately vigorous crowns with average width or narrower, and length less than 55 percent of the total height; either short wide crowns or long narrow ones, but neither sparse or ragged; position, usually codominant but sometimes isolated or dominant; diameters above average for age.

C:-- Fair to poor crowns, very narrow and sparse or represented by only a tuft of foliage at the top; foliage usually short and thin; position usually intermediate, sometimes codominant, rarely isolated; diameters below average for age.

D:-- Crowns of very poor vigor; foliage sparse and scattered or only partially developed; position suppressed or intermediate; diameters decidedly subnormal, considering age.

Figure 11 pictures the various classes as they will be found in the forest.

Table IV gives a comparison of Keen's and Dunning's classifications.

This classification with its wide coverage is perhaps the best of the lot. It gives sixteen classes to choose from instead of the seven of Dunning's, while both are based on the same principles, namely, general vigor and crown development.

As for susceptibility, the main idea behind this classification, Keen(30) lists the following chart, running from highest to lowest risk:

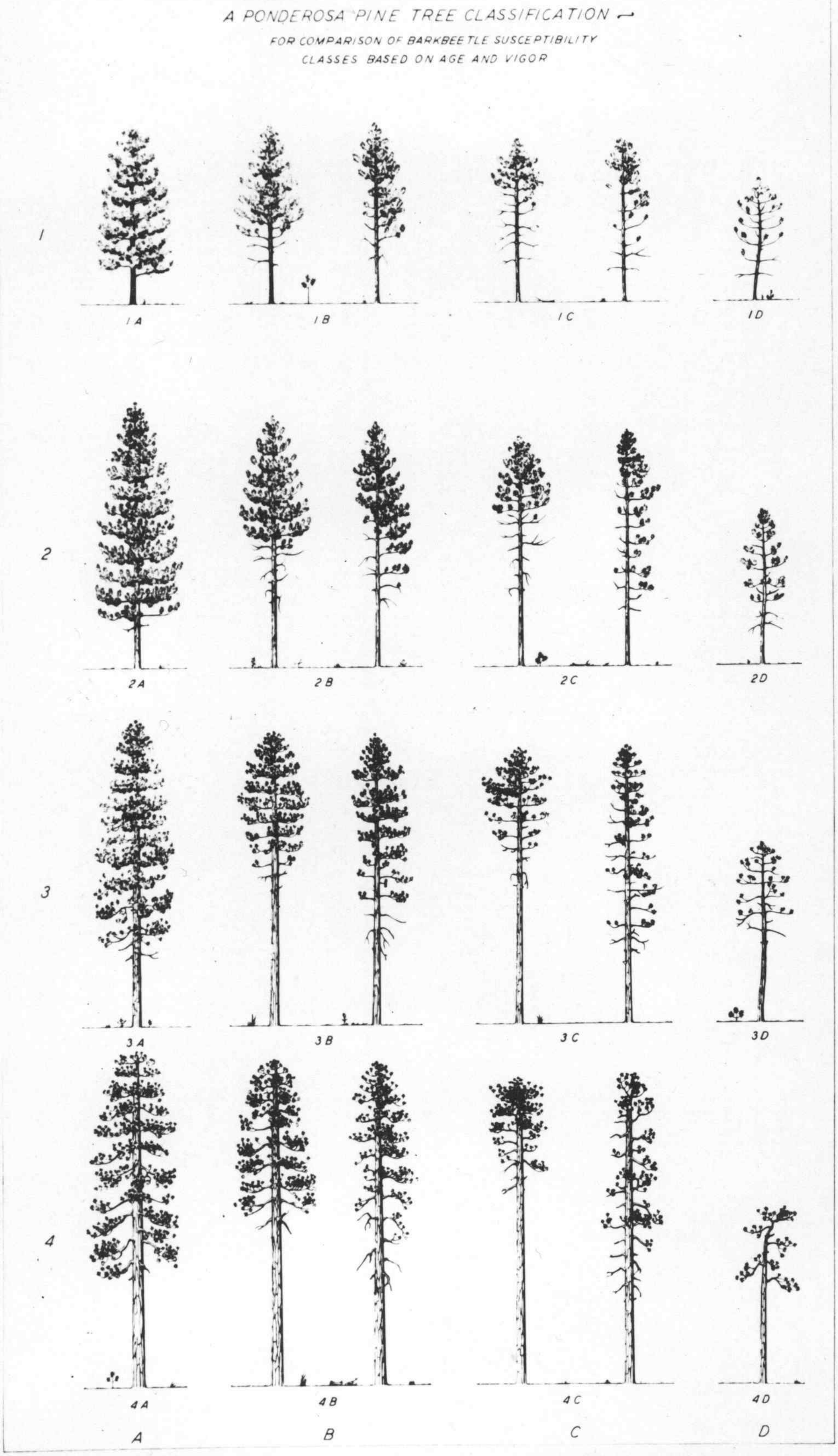
Table III:---

Order of Susceptibility.	Tree Class	Ave. Diam.	Ave. Vol.	Mort. Ratio	Ave. % Trees Killed per Year
		SUSCEPTIBLE TYPES			
1	1D	10	30	2.50	4.1
2	2C	16	160	2.24	3.9
3	4C	28	1,280	2.18	3.9
4	3C	21	540	1.60	2.9
5	1C	12	60	1.58	2.8
6	3D	14	140	1.33	2.4
7	4D	18	300	1.32	2.4
8	2D	12	70	1.20	2.1
		INTERMEDIATE TYPES			
9	4B	32	1,790	1.16	2.1
10	3B	26	930	1.10	1.9
11	2B	19	300	0.98	1.7
		RESISTANT TYPES			
12	1B	14	100	0.49	0.9
13	4A	35	2,200	0.48	0.9
14	3A	27	1,100	0.41	0.7
15	2A	20	370	0.32	0.5
16	1A	14	100	0.17	0.3
AVERAGE				1.00	1.8

These figures apply only to the 15,000 acres of sample plots in the Klamath Region of Southern Oregon--Northern California, and to the period studied from 1928 to 1931, inclusive.

Examples of the use of Keen's classification cover

Figure 11 Keen's Classification



a wide range. It has been almost universal in the ponderosa pine regions as a tool of management. Like all classifications it is not foolproof and its application is most exact for the typical ponderosa pine, site IV for which it was originated(16). Modifications of this classification are used in R-5(26), Arizona(32), Colorado(1), and in other widespread ponderosa pine regions.

Table IV

COMPARISON OF KEEN'S AND DUNNING'S CLASSIFICATIONS

Classes defined by Dunning	Bark beetle susceptibility classes defined by Keen
1	1A, 2A
2	1B, 2B
3	3A
4	3B, 3C
5	4A, 4B, 4C
6	1C, 2C, 1D, 2D
7	3D, 4D

Or, in reverse order:

Bark beetle susceptibility classes: Age group	Vigor group	Dunning's classes
1	A, B, C, D	1, 2, 6, 6
2	A, B, C, D	1, 2, 6, 6
3	A, B, C, D	3, 4, 4, 7
4	A, B, C, D	5, 5, 5, 7

In R-6 the closest example of this classification being used as a tool of management and indirectly as a decided prevention of potential insect losses is found in the Burns Working Circle of Eastern Oregon. Oliver Ericson (11), of the R-6 regional office, explains the application of Keen's classification on this job by showing the type of trees removed in the selective cuttings. He says that we will generally take 4C, 4D, 3C, and 3D trees. 2C trees, if over 20 inches, will probably be taken. These five classes are among the first eight listed by Keen as most susceptible. The other trees of the eight are 1C, 1D, and 2D, all of these falling below the economic cutting limit. This in itself seems a high tribute to the entomologist in his upward struggle to combat the insects in a successful indirect control method.

The most recent, and to the writer who has had the opportunity to watch it grow to prominence from its inception in 1934, the most interesting classification is the one based on the workings of two species of the Melanophila beetles.

Prior to 1934 the species Dendroctonus brevicomus Lec., the western pine beetle, received the credit of being the greatest primary insect enemy to ponderosa pine. In many regions this credit is still given, and in some cases may be justified, but in other regions this appears doubtful.

Let us consider how the cause of death of a tree is determined. On the direct control project the spotter will have a book of tags similar to the facsimile shown below:

Table V:

Project area No.______ Unit_______ Tree No. ________

Killed by__________________ Location ______________

Year______ Summer brood______ Forty___ Sec.____T____R___

Year______ Winter brood______ Owner__________________

	D. Brev.	D. Mont.	Ips	FOLIAGE	Yellow pine
Attack				Green	Sugar pine
Parent adult				Fading	
Eggs				Sorrel	D.B.H.
Larvae 0-.5				Red	# 16' logs
Larvae .5-1				Black	B. F.
Pupae					
New adults				Remarks:	
Emerging					
Abandoned				Date_____	Camp No.________
Invested length				Spotter______________	

He slashes the bark with his axe and discovers some shot-like holes. A little more bark is removed and the tell-tale galleries of Dendroctonus brevicomus Lec. will appear. Possibly some galleries of D. monticola Hopk., Ips or flatheads will be found also, with the western pine beetle predominating. The spotter blazes the tree and tags it while the compassman maps it in. They move on and the tag eventually gets to the office, the tree being recorded in a great number of cases as having been killed by D. brevicomus. This examination has all been within five feet of the ground and of the remaining 3, 4, or 5 logs very little is known. It would appear to be rather poor sampling to say that the primary cause of death, entomologically speaking, was from an attack of western pine beetles. Even when a stem analysis is made of infested trees we may not arrive at the primary cause of death, that is to say, the primary insect of a number of forest insects in the chain of events leading to the final outcome. We may find Dendroctonus valens Lec. in the base, D. brevicomus, Ips or flatheads in the bole, and Ips or flatheads or both in the top. Which came first? Dead tops may indicate that flatheads weakened the tree so that Ips or Dendroctonus beetles were able to kill it. Maybe the Ips beetles weakened the tree so that the flatheads and Dendroctonus beetles could finish the job. One thing appears very definite, however, in a study of this kind. When enough western pine beetles hit a tree, regardless of vigor, the tree is doomed. However can the D. brevicomus be considered primary when other beetles have paved the way? According to Salman(26), generally speaking, the only absolute primary infestation that can be properly credited to the western pine beetle, is the grouping occuring in epidemic conditions. Up to date, the phenomena of grouping has never been satisfactorily explained. It seems indeed strange that groups ranging from a few to more than one hundred trees, thrifty and poor ones alike, may be entirely cleaned out by single broods of D. brevicomus.

Working on this study of primary insects in ponderosa pine, Dr. A. S. West, Dr. K. A. Salman, Jack Bonberg, Philip Johnson and other California entomologists began an intense study of the genus Melanophila. This study resulted in the tree susceptibility classification based on characteristic tree appearance due to infestations of Melanophila californica Van Dyke and to a lesser extent M. gentilis.

The study of M. californica Van Dyke and M. gentilis Lec. is quite interesting in that it exposed a comedy of errors in the classification of the beetles and their work. Burke(4) concluded that the pitchy scars surrounded by radiating pitchy galleries, common to pönderosa pine, were diffused or small lightning scars where the adult flatheads had been attracted to lay their eggs. West(29) proves this incorrect by showing that the galleries run <u>into</u> the scar not away from it, and that they are the cause, not the effect of the scars. Burke also considered that M. gentilis was a major cause of death to pines, in a strictly secondary role, and that M. californica was of importance only in slash and dead or dying trees. Studies by West(29) upset this theory also as he shows that M. californica is a much more serious pest to living pines than M. gentilis, whose major activity is centered in dead and dying material. West also pretty definitely proves that for specific regions (the study has only been centered in parts of the Modoc, Lassen and Shasta National Forests) the flathead beetle, Melanophila californica Van Dyke is primary in its attacks on pines in many cases.

The studies made of the two species have been very limited in the past, only a few notes being found in the entomological journals, some of these erring rather sadly.

In the study of these sun loving beetles we find many interesting sequences. Any one familiar with fire control in the ponderosa pine regions has undoubtedly become acquainted with M. acuminata. These black, hard shelled beetles are often found where the smoke and heat are the most intense, laying their eggs in the bark and quite often annoying the fire fighters by nipping them on the arms and neck. M. gentilis is quite similar to this beetle, being a trifle smaller and having a characteristic greenish iridescense. M. californica is a bronze tinted beetle of the same general outward appearance. Tannish spots are common on the wing covers. These insects lay their eggs in the deep bark crevices, the larvae soon hatching and boring into the cambium. Here their tiny galleries start out directly between the wood and the phloem. Now we meet a strange quirk of nature. In this tiny larval stage, termed <u>incipient</u> by West(32), there is no definite time limit for the larvae to grow, pupate and emerge as adults. They may go through this natural sequence in one year or they may remain in this tiny incipient stage for several years before the continuity is carried on. Being directly in the cambium during this incipient stage, their tiny galleries are healed over directly behind the slow moving larvae. Microscopic studies made by Salman and West(29) trace the galleries from beginning to end, the exact dates being recorded by the number of annual rings layered over the scars. These galleries result in the many indistinct line-like ridges so often seen on snags of the ponderosa pine forests. After varying lengths of time spent in the incipient stage the larvae undergo a period of very rapid growth to the prepupal stage. This is shown by the widening of the small galleries and the packing of the new ones with the characteristic arc-like layers of frass. These wide galleries do not heal over as do the incipient ones(29). This rapid growth is followed by another pause of a varied length during the pupation stage which is spent in the outer bark. Emergence begins in May and June and varies directly with the temperature, the heaviest emergence being directly correlated with the warmest temperatures(32). Mortality is very high in the larval stages, particularly in the incipient stage, and the average life of the adults with caged specimens is four days(32).

In the examination of a tree infested with flatheads we may find the peculiar situation of having incipient larvae of several different broods, rapidly growing larvae of the same varying ages, and possibly some pupae and adults. West(29) says that the time spent in the incipient stage varies with and depends upon the condition of the host.

Salman(32) sums up West's studies in a letter to Dr. Craighead, March 15, 1937:

"It has been concluded from the composition studies and from the flathead projects:--

a. That flatheads attack green trees.
b. That those attacks are resisted by most trees - sometimes successfully. Apparently successive broods may make a succession of attacks on the same tree.
c. That under all infestation conditions sampled in California during the past five years in the stem analysis studies, flathead borers were successful in their attacks in 52% of the trees that were examined.
d. That where flatheads occured they usually attacked before other species of forest insects concerned in the infestation.
e. That <u>D.b.</u> and other supplementary insect attacks ordinarily obscured the incipient flathead attacks. As a result there is no way of knowing how many more of the trees that were examined actually harbored preliminary flathead infestations.
f. That with the exception of groups of snags resulting from engraver beetle or western pine beetle outbreaks, few weathered snags do not show the results of incipient flathead attacks that preceded the death of the trees.
g. That the fast growing larval stage of flatheads, which is described in West's report, must have been reached in many trees before the attack by other species occurred.
h. That the fast growing larval stage is an indication of the overcoming of the resistance in the tree or the part of tree that has been infested."

With the study of the two species of Melanophila becoming very intensive, it was noted that the trees harboring flatheads assume a very characteristic appearance. Thus a classification of flathead trees was evolved. This classification rates trees on their appearance in conjunction with the possible number of years that the tree will live. The first classification was an A, B, C spread; the A trees being quite thrifty, the B trees being definitely on the wane due to flatheads, but still capable of living for several years under normal conditions, and the C class, which included trees doomed to die within a very short period. Soon the classification was broadened to include two classes of B trees, and finally in 1937 Bonberg(2) presented the present classification:

"Susceptibility Class 1.
Trees without any outward appearance of weakening. Needles long and coarse. Crown dense. Twigs holding needles numerous. (See Figure 13)

Susceptibility Class 2.
Slight visible evidence of weakening. A few twigs dead or twigs dying in portions or in the entire crown. (See Figure 14)

Susceptibility Class 3.
Definite evidence of abnormality in tree as indicated by: Shortening of needles, thinning of crown, numerous dead or dying twigs or branches, and definite top weakening. (See Figure 15)

Susceptibility Class 4.
Undisputed evidence of decadence. Needles short. Needle bunches thin. Foliage thin. Few twigs holding needles. Top killing infestation active. Previous top killing weakening tree. (Usually a combination of two or more of the above characteristics. Active top killing sufficient to classify as a 4.) (See Figure 16)

Figure 12: Typical example of a ponderosa pine attacked by Melanophila californica. Taken on the Lassen N. F. by J. E. Patterson 7/22/36

Figure 13: Melanophila tree susceptibility class #1.
Photo by K. A. Salmah. 6/21/37

Figure 14: Melanophila tree susceptibility class #2.
Photo by K. A. Salman 6/21/37

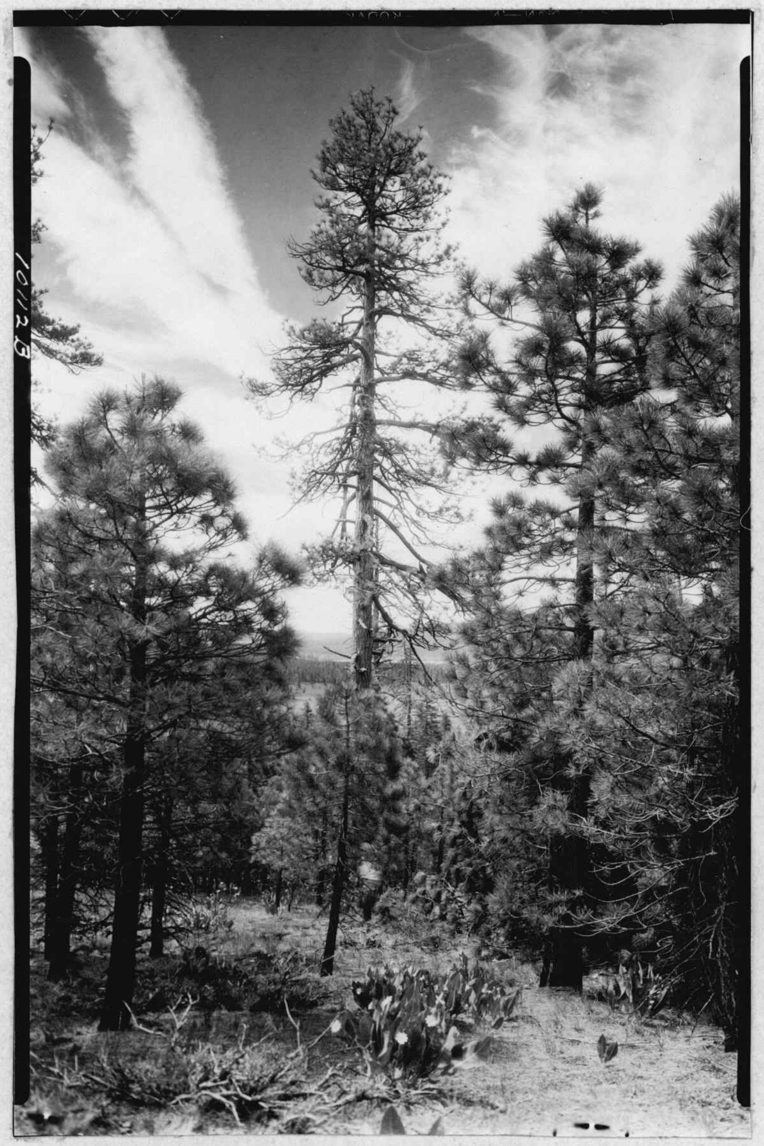


Figure 15: Melanophila susceptibility class #3.
Photo by K. A. Salman 6/21/37

Figure 16: Melanophila susceptibility class #4.
Photo by K. A. Salman 6/21/37

Bonberg is using this classification on the Black Mt. Experimental Forest(31) and its efficiency appears to be becoming established. According to West(31), the Experiment Station is removing all of the class 3 and 4 trees and such additional ones that will produce a $2.50 stumpage value. If this proves feasible in an economic sense, the losses due to Melanophila and other insects should decrease appreciably as a result of the better general health of the stand, and we would have a saving of the trees that would succomb prior to the next cutting.

This method will not be universal in application to ponderosa pine forests and it may be only a local condition. It is being studied and applied in the Modoc and Lassen National Forests in conjunction with the Forest Service and the Experiment Station and in this experimental stage appears to have great merit. It is justly described as a step in the right direction.

Indication of Hazard Areas:

Salman and staff(31) closely followed by Keen began in 1936 and 1937 to take particular note of certain annual losses occurring in specific areas of ponderosa and other pines, and after a lengthy study concluded that certain areas could be normally expected to have a greater annual loss than others. They hit upon a plan of mapping areas according to the normal expected hazard. These maps would be used by lumbermen in their annual cuttings with the general idea of cutting these hazardous sections first thus utilizing trees that might fall before the inset of insect depredations. Maps of this order would be invaluable to the Forest Service in determining where cuttings should start in their working circles, and as an indication of the most logical percentage of cut to take in the first cut.

As I understand it, Keen(17) has based his hazard ratings on indicator species, presence or absence of certain species indicating relative susceptibility of the immediate area. His first broad division is based entirely on topography with rivers and ridges forming the boundaries. From this it is broken into smaller units quite comparable to working circles and groups, these being based on indicator species with the susceptibility rating being assigned to smaller subdivisions. Due to the comparative newness of this rating, no maps or photographs were available at the Portland office, and data being collected is as yet unpublished.

Salman's rating(31) is based altogether on past and current losses established by strip cruising. Regarding this rating West says:

"We are making five hazard ratings. One cruise completed is of the Eagle Lake tract owned by Fruit Growers and Red River, consisting of 26,000 acres, which was divided into 6000 acres 3rd class, and the remainder fourth class. If the past losses for the period of time normally covered by the survey amounted to 10-20% of the stand, the area was rated in class 3, and if the losses ranged from 20 to 35% of the stand a class 4 rating was applied. However, this was based on 1936 work and it is not implied that class limits are fixed and certain. Development of the conception of classes is still in a developmental stage and progress of the work will undoubtedly result in some changes in classification. In addition to past losses, living pines on the strips were cruised and classified according to susceptibility. The susceptibility of stand was rated according to the proportion of highly susceptible trees on the area. The percent of three needle pines killed during the last ten years in the period on typical areas is shown:

Table VI:

Hazard class of area	Pine stand per acre Trees	Volume	Loss per acre Trees	Volume	Percent Killed
III	13.8	15,923	1.7	2,279	12.5
IV	13.3	12,754	3.1	3,707	22.5
Ave. entire area	13.4	14,231	2.4	3,037	17.6

Health of the green trees must play an important part in the hazard ratings, and here is where our susceptibility comes in as a measure of the condition of the living stand. Susceptibility of the trees should show what losses may be expected in the near future, bearing in mind that future losses will be affected greatly by future environmental conditions. Susceptibility figures should supplement past loss figures and have a similar value in determinging hazard rating."

Thus we find this classification based directly on the health of the stand measured in individual tree health and past loss figures. As example of these various types of ratings, Figures 17, 18, and 19 show typical pine stands of northern California with their susceptibility ratings. Pictures of ratings 1 and 2 are not available.

Figure 17: Hazard area #3 in a mixed conifer type of stand near Bogard Butte, Lassen National Forest. Photo by K. A. Salman 1937.

Figure 18: Hazard area #4, Lassen National Forest, on Goose Lake Road in a two story type of stand. Photo by K. A. Salman 1937

Figure 19: Hazard area #5 along Hat Creak in the Lassen National Forest. Photo by K. A. Salman. 1937

CONCLUSION

We have now brought the picture of insect factors in ponderosa pine management up to date. To be sure this is perhaps only the beginning. With the perfection of susceptibility ratings for individual areas, with the selective logging of ponderosa pine becoming more possible each year through improved logging practice and equipment, with the advent of small mills, and with our modern intensive fire control planning, we have made large steps in the hope of cutting down substantially the greatest of our losses in ponderosa pine forests of Oregon, Washington and California. We have a long way to go yet. Many factors studied in the past, and many to be studied in the future will bear on this problem. As foresters, we have a definite part to play in this sequence. The words of J. F. Preston (25) are well fitted to express this view:

> "I want to again emphasize the statement that the control of insects is primarily the forester's job. The technique of methods must be prescribed by the entomologist, but the responsibility for the protection of the forests against insects must rest squarely on the forester's broad shoulders."

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