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The Western Pine Beetle in Oregon

by

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A Thesis

Presented to the Faculty

of the

School of Forestry

Oregon State College

In Partial Fulfillment

of the Requirements for the Degree

Bachelor of Science

June 1938

Approved:

Professor of Forestry

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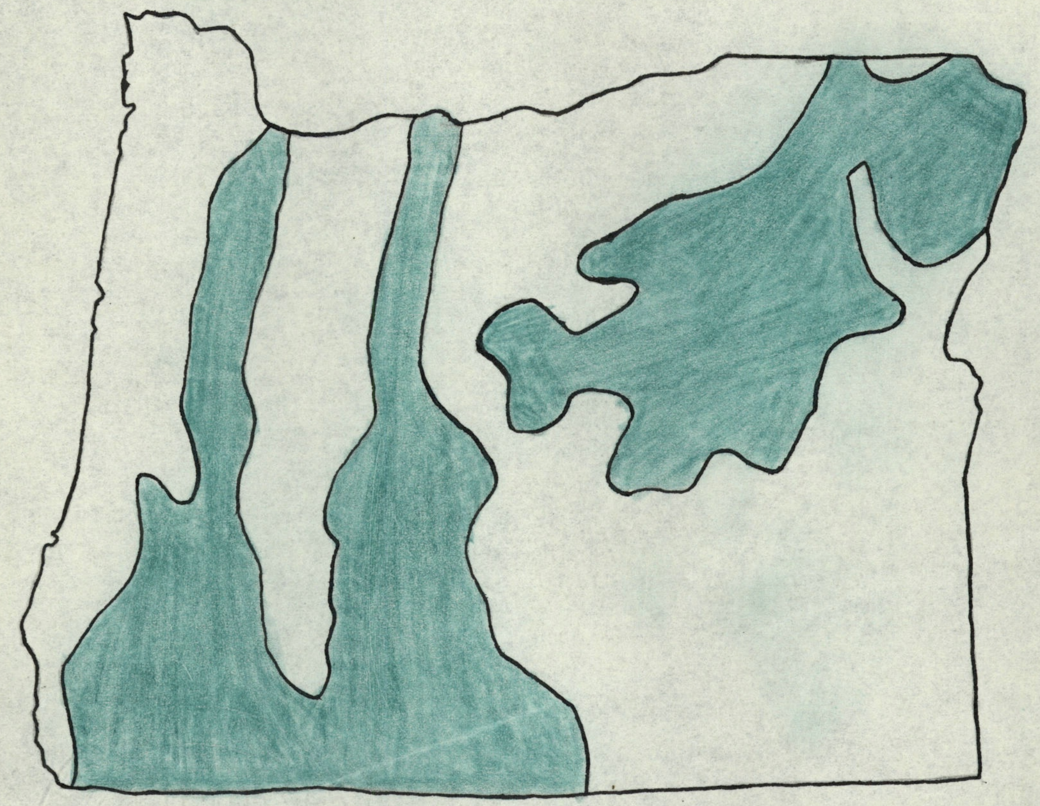


Map showing the distribution of yellow pine in

Oregon

Oregon's greatest natural resource at the present time is its forests, and the State may well be proud of its magnificent stands of virgin timber excelled by none and equalled by only one other state. These wonderful forests are the mecca of thousands of tourists, who love the mountains and forests; insure to our cities an adequate supply of pure mountain water; maintain an even flow of our streams for water power; protect our fishing industry; furnish cover for game; supply our own timber needs; and produce the raw materials for extensive manufacturing concerns. Over 40% of the population of the State of Oregon gains their livelihood from the forests.

From these considerations it is clear that the protection of the forests is of vital importance, not alone to the timber owners but also to the State, whose welfare, income, and prosperity depends to such a large extent upon this resource. These forests if once destroyed, can be replaced only by careful guarding through many generations, since the average age of the trees being cut from the stands of yellow pine in Oregon is in excess of 200 years and it takes about 90 years to produce a tree twelve inches in diameter.

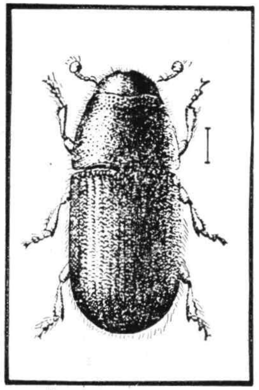
The problem of protection, however, does not mean safeguarding the forest against fire alone. There are other sources of injury that may cause widespread damage. The most important of these sources is the suppression and holding in check of insects that are injurious to forest trees.

THE IMPORTANT DENDROCTONUS BEETLES

OF

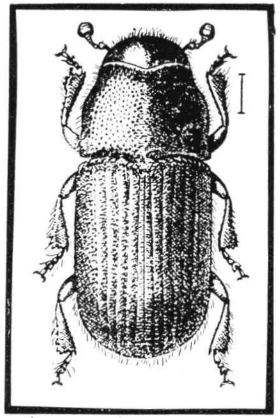
OREGON AND WASHINGTON

WESTERN PINE BEETLE
(D brevicomis Lec.)



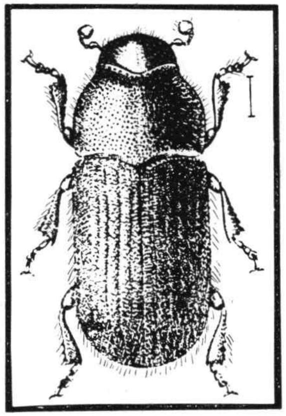
Kills
Ponderosa Pine

MOUNTAIN PINE BEETLE
(D. monticolae Hopk.)



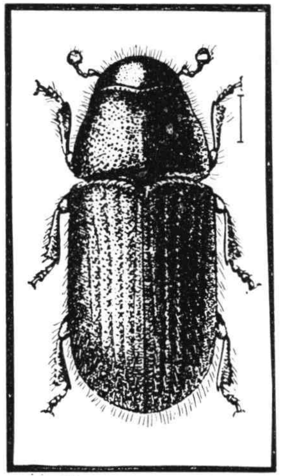
Kills
Lodgepole Pine
Ponderosa Pine
Western White Pine
Sugar Pine
Whitebark Pine

DOUGLAS FIR BEETLE
(D. pseudotsugae Hopk.)



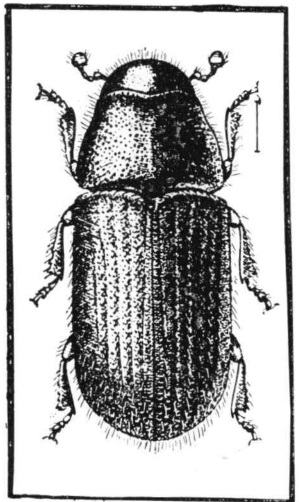
Kills
Douglas Fir.
(Primarily east of Cascades)

ENGELMANN SPRUCE BEETLE
(D. engelmanni Hopk)



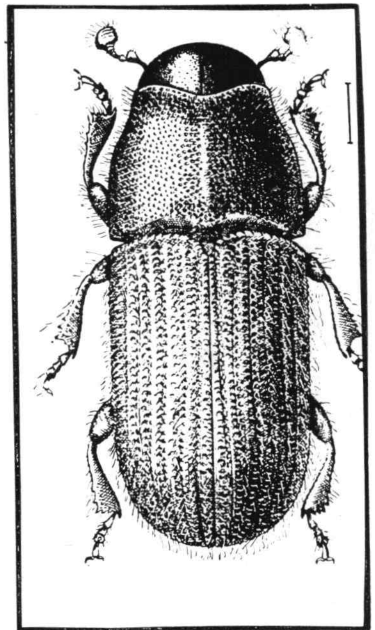
Kills
Engelmann Spruce

SITKA SPRUCE BEETLE
(D. obesus Mann.)



Kills
Sitka Spruce

RED TURPENTINE BEETLE
(D. valens Lec.)



Attacks
Base of all species of Pine.
A few other Conifers.

Much enlarged. Average actual size shown by hair line at right of each insect.

One of the most serious insect enemies attacking ponderosa pine is the Western Pine Beetle, (Dendroctonus brevicomis Lec.). Every year throughout the entire range of ponderosa pine from lower California to British Columbia many of the largest and finest of these pines fall victims to these tiny insects. The total destruction measured in board feet or in dollars is enormous. However, much of this is only the normal loss since in any one locality not more than one-third to one-half of one per cent of the stand is killed in any one year. But frequently, in some localities particularly favorable to the beetles, they build up their numbers until hundreds of trees in every square mile are destroyed. And in one year, as much as ten per cent of the stand may be killed. Such a situation is called an epidemic and calls for action on the part of the timber owner if he values his timber crop at all highly, and wishes to save as much of it as he can from destruction.

The adult beetle is a rather stout, brownish or black beetle, from 3 to 5 mm. in length, with a broad head grooved in front, the pronotum narrowed toward the head and coarsely punctured. The wing covers have fine elevated lines. The beetle is clothed above with very short, almost microscopic hairs.

The larva or worm emerges from the egg as a tiny, wrinkled, white, legless grub with a dark head and strong jaws.

The western pine beetles develop and work so rapidly that trees which are attacked in the early summer are killed and abandoned before fall and their progeny are at work on other trees which are killed before winter. It is in these later attacked trees that the beetles spend the winter in a semi-dormant condition.

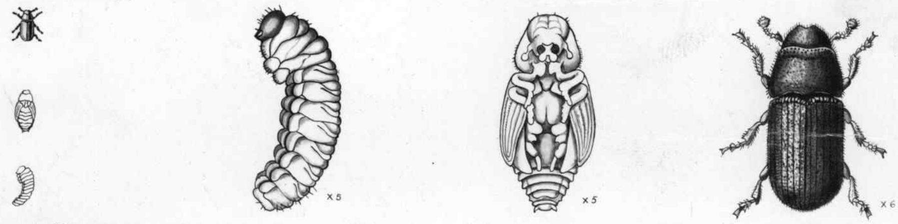
After emergence from the dead trees the new beetles enter a period of flight, after which they concentrate upon certain trees to which they are attracted and start their attacks. The first attacks on a healthy tree usually start near the top and the beetles keep coming in numbers for a period of several days or a week until the natural resistance of the sap flow of the tree has been overcome and the girdling of the tree by the egg galleries has been completed. A successful attack required about 24 parent adults to a square foot of bark or about 7,000 beetles to a 24 inch 5-log tree.

Within a week or two after the attack, the tree dies. The parents mine their egg-galleries and deposit eggs which hatch in about seven days. The grubs feed upon the sap of the dead trees, complete their growth, change to pupae, then to new adults and finally the new broods leave the tree. These new broods emerge from the summer-killed trees during August, September, and October. From actual counts, it has been found that enough new beetles are hatched from a single infested tree to kill eleven other trees provided all the beetles made successful attacks.

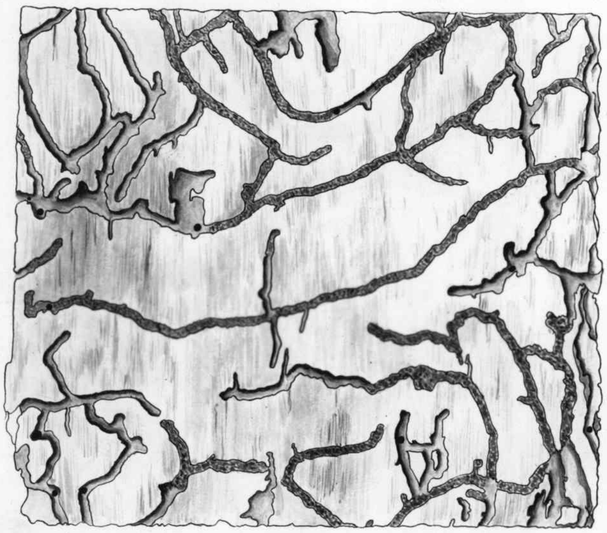
The beetles which emerge from the "summer trees" attack and kill new trees during September, October, and

THE WESTERN PINE BEETLE

— DENDROCTONUS BREVICOMIS Lec.



Natural Size | Larva | Pupa | Adult



Egg galleries on inner bark surface
one half size

An infested tree trunk with bark removed

A western pine beetle epidemic in a ponderosa pine forest

November. After the attack, eggs are laid and the development of the brood continues until it is stopped by the cold winter weather. The insects then pass the winter in all stages of development, namely as parent adults, eggs, larvae and occasionally pupae and new adults.

Those individuals which passed the winter as newly transformed, or young adults will leave the parent tree in May or June. From this time on there will be almost a constant emergence of adult beetles from the infested trees due to the continual development and transformation of mature larvae. The principal period of attack by the emerging beetles is in July and early August. (1)

The adult beetles dig through the bark of healthy, injured, fallen or standing timber and excavate winding galleries in which the eggs are deposited. The eggs hatch in a week or ten days. The young larvae bore their winding galleries through the inner bark. The length of the larval stage varies considerably. The summer brood spends nine to twelve weeks as larvae. The over-winter larvae are in that grub stage for over six months, being inactive during the cold, winter weather. The pupal stage covers a period of three to four weeks.

The important aspects of the life history and habits of the western pine beetle are:

1. The larvae of this insect pass most of their life in the middle layers of the bark.

2. The insects emerge through small, shot-like holes around which there will be no resin tubes. The presence of large numbers of these exit holes in trees with yellowish or reddish foliage indicates that the broods have matured and left the tree; no time or money should be wasted on these "beetle-abandoned" trees.

3. Careful examination should be made of all timber near beetle-abandoned trees to ascertain if the broods, which recently emerged, have not attacked these trees.

4. A tree may remain green even up to the time that the majority of the beetles have left it. The foliage of infested trees usually begins to fail in late summer, turning yellow in fall and winter and becoming a "red top" the following spring.

5. As a rule the emerging swarms of beetles attack living trees in the immediate vicinity of the parent tree, but at times these swarms fly considerable distances and attack isolated trees or clumps of trees, thus establishing a new center of infestation from which succeeding broods will work out in all directions.

Usually the first evidence that a tree has been attacked by these beetles is the sickly pale color of the needles. The faded appearance gradually changes to a yellow or sorrel and then to a bright red. In the first fading of the tree, the needles die from the center of the needle clusters outward and usually from the top of the tree downward. During the normal process of shedding the old needles a tree sometimes has so many dying needles that it resembles an infested tree although it may be perfectly healthy. However, it will be noted on these healthy trees, the center of the needle clusters at the tip of the branches are green, while an infested tree is characterized by the dead tip with possibly green needles further back on the branches.

On closer examination of the infested tree, small circular holes about 1/16 of an inch in diameter, will be noticed in the bark, usually in the crevices. A very small amount of sawdust will be found in some cases, and occasionally pitch tubes cover the holes through which the beetles forced their entry into the tree. Upon chopping into the suspected tree so as to expose the sap wood and inner surface of the bark, the winding egg-galleries will be found in the inner bark. These egg galleries, which are slightly larger in diameter than the beetle, are filled with sawdust and cross and recross each other in such a manner as to form a network of irregular lines. This peculiar type of egg-gallery is characteristic of the species and can be said to be the hieroglyphic or signature of the western pine beetle.

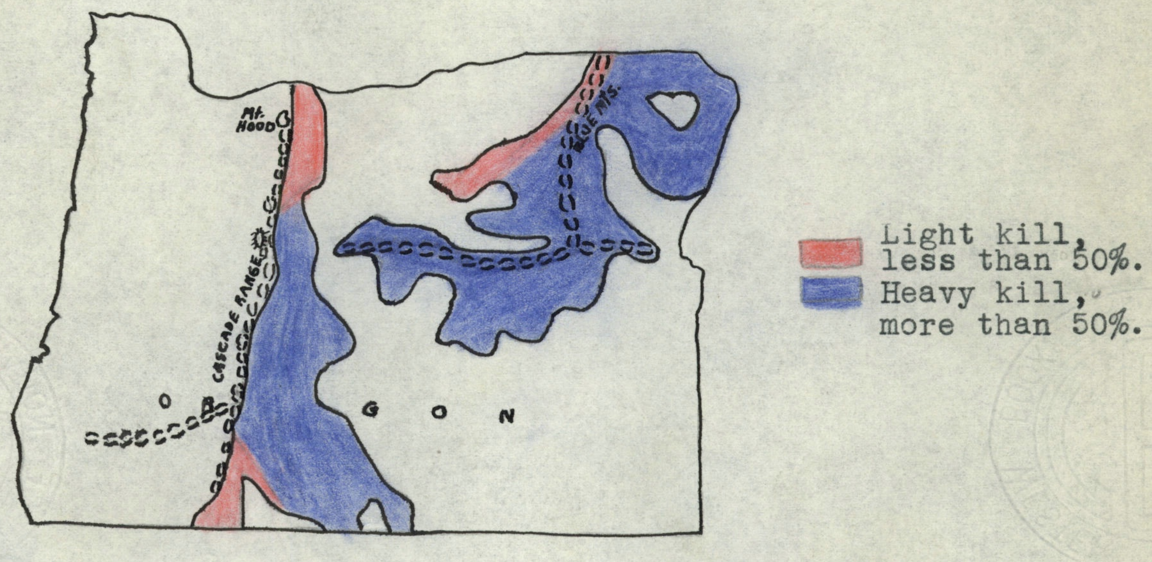
If the tree has just recently been attacked the bark will still be tight on the sapwood, not discolored, and the fresh dark brown beetles will be found in the galleries with small white eggs about the size of a pin point deposited in little niches on the walls of the gallery. Sometime after the attack, the inner bark withers, becomes discolored and brown and loosens from the tree. At this stage the parent beetles will be found at the end of the egg-galleries where they finally die.

After the eggs have hatched, the small worms burrow for a short distance in the outer bark where they reach maturity, transform to the pupae or resting stage and then change to new beetles. These new beetles are at first very light in color but gradually they darken as their shell hardens. Soon they are ready to emerge and to attack other trees.

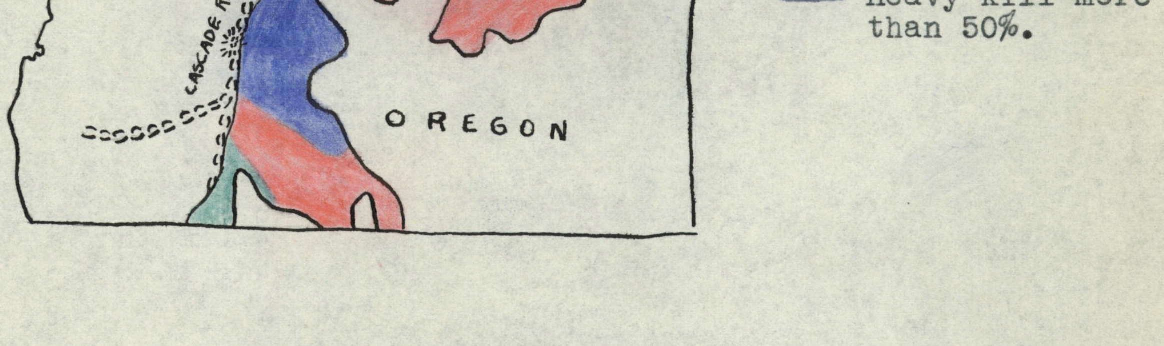
On leaving the tree each beetle burrows out for himself leaving a neat round exit hole in the bark, so that the tree from which many beetles have escaped looks as though it had been peppered with bird shot. Trees in this condition should never be felled or burned as the destructive pine beetles have already escaped and only the predatory insects which prey upon them and leave the tree after the emergence of the beetles, will be destroyed.

Importance of temperature as a limiting factor in the distribution and seasonal abundance of insect species has long been recognized. Each species, through adaptation, has become adjusted to life within the range of temperatures prevalent in its natural habitat. Even so temperatures, may occasionally occur that are fatal to part of an insect population. Mortality of an insect

Winter kill of Dendroctonus brevicomis, December 1932
and February 1933



Winter kill of Dendroctonus brevicomis, November 1935



pest, as the result of critical temperatures, may influence its seasonal abundance at times and hence be an important consideration in determining whether or not to adopt direct control measures.

The western pine beetle is a transition zone species inhabiting the Pacific Coast portion of the range of ponderosa pine from Baja, California, to British Columbia, and eastward into Idaho and Montana. In this area it is normally subjected to air temperatures of -10 to 105° F. Since critical temperatures for this beetle lie below -5° F. and above 105° F., it is apparent that the species, being protected to some extent by insulating layers of bark, is well adjusted to the usual temperatures in its geographic range.

In certain parts of its normal range, abnormally low temperatures, which are fatal to part of the overwintering broods, occur from time to time. On the western slopes of the Sierra Nevada Mountains and in the southern portion of its range subzero temperatures sufficiently low to cause western pine beetle mortality rarely occur, but on the eastern slopes of the Sierra Nevada Mountains and Cascade mountains and in the northern part of its range such temperatures are more frequent. In central Oregon, which is typical of the entire area covered in the present study, there is appreciable winter killing of western pine beetle broods about one in every three years, and severe killing perhaps once in 10 years. These killing temperatures cause an immediate reduction of western pine beetle populations which, in certain instances, is reflected in a temporary decrease of damage to the host tree. Temperatures within its normal range do not fall sufficiently low to exterminate the beetle population, and infestations soon resume their normal course, which is primarily influenced by other factors. There is evidence that the northeastern limits of distribution of the western pine beetle are determined by minimum winter temperatures.[2]

For the western pine beetle, as for any insect species, there is a more or less constant death rate during the developmental period. This may be termed the normal or usual mortality, and must be determined before the abnormal mortality can be recognized.

Population counts at different stages of western pine beetle development, which were made over a period of 11 years in the same general region have been summarized in a report by Keen. These counts show the following averages; 432 eggs are laid to each square foot of infested bark, 346 larvae hatch, 200 reach the full-grown larval stage, and only 63 adult progeny emerge from the bark. Thus the normal hazards of life for the western pine beetle, under all conditions from the egg to the adult stage, causes a reduction of about 85 per cent.[3]

Even in mild winters there are several months in which no transformations take place. During the quiescent winter period, brood mortality is usually not in excess of 5% when killing temperatures do not occur. This has been shown through the examination of several thousand square feet of bark containing overwintering broods of different stages and from many different areas.

Eggs and small larvae, which overwinter in the phloem or very close thereto, appear to experience such altered conditions of food and environmental moisture that, upon resumption of activity in the spring, very few are able to complete their development. Caging studies by Buckhorn have shown that, in mild winters, trees containing overwintering eggs and small larvae have produced only about 20 per cent as many progeny as those with overwintering large larvae. Thus the normal hazards for overwintering small larvae are much greater than for large larvae.

Winter mortality caused by low temperature is easily recognized, for the dead larvae present a characteristic leaden appearance which can be duplicated by exposing healthy brood to low temperatures under controlled conditions. Accordingly, when excessively low temperatures have occured in the field, it is possible to determine the presence or absence of winter killing by direct observation. This reduction of brood by freezing can be measured rather accurately by sampling the population soon after low temperatures occur.

The effect of low temperatures upon western pine beetle broods under field conditions depends upon several important factors, particularly the temperature to which broods are exposed, the environmental conditions surrounding them, and the condition of the broods.

Subcortical temperatures to which broods are exposed depend on the air temperatures in the forested area modified by the insulating properties of the bark. During cold weather subcortical temperatures do not fall as low as those of the air, the differences being governed chiefly by bark thickness and the rate of temperature change. Not only is there a difference of as much as 29° F. between air and subcortical temperatures in bark of varying thickness, but there is a lag of one to two hours in the reaction of bark temperatures to air-temperature changes.

Difference between air and subcortical temperatures varies considerably, being influenced primarily by the rate of change of air temperature. The more prolonged the cold, the less the difference between air and bark temperatures; however, extreme temperatures in the range of the western pine beetle do not last long so that there is always considerable differential between the lowest air temperature and that in the bark where the brood is located.

That this protection afforded by insulating layers of bark influences the amount of brood mortality during periods of extremely cold weather has been shown in all of the studies made so far. In general, as stated by Miller and Beal, brood mortality varies inversely as the thickness of the bark in which the brood overwinters--i.e., the thicker the bark the less the mortality.[4]

In experiments with solar heat as a lethal agent there is no means of controlling the degree of heat to which the bark is exposed, as this is dependent entirely upon weather conditions. It is obvious that the only course open to the experimenter is to record the temperature developed within the bark and compare them with the resultant mortality of the broods. However the quantity of heat that is absorbed by the bark varies decidedly with the angle at which the bark is inclined toward the sun. The maximum is reached in the middle of the day, provided the bark is placed as nearly as possible with its surface at an angle of 90° to the sun's rays. On a standing tree the bark surface of the main trunk is vertical, and therefore nearly parallel to the direction of the sun's rays at midday during the summer season. This position, together with the contact of the bark on the sapwood, results in conditions which keep the bark temperatures well below those producing mortality, even though infested bark on the lower part of the trunk may be exposed to the sun at midday.

The readings taken from an infested tree shows that the temperature of the bark placed on the ground climbed rapidly when exposed to the sun until 1:30 P. M., when it reached a maximum of 104° F., or 38° higher than the corresponding air temperature. After 1:30 P. M. the temperature of this bark declined slowly until 2 P. M., when the shade came, it fell rapidly during the next hour.

The bark exposed to the sun on the south side of the tree did not become much warmer than the air in the shade until 12 P. M. Its temperature reached a maximum of 74° F. at 2 P. M., or 8 degrees higher than the air temperature at 1:30 P. M. This bark did not begin to cool until 2 P. M.

The temperature of the bark on the north side of the tree lagged well below the temperature of the air and of the bark on the south side throughout the period of sunlight. After 2 P. M., as the temperature of the air became lower, the bark attached to the tree retained its heat, and its temperature on both the north and south sides was higher than the air temperature of 3:15 P. M.

This experiment indicates that infested bark attached to a standing tree does not become more than 10° warmer than the corresponding air temperature in the shade, and that it is necessary to remove infested bark and expose it flat on the ground in order that it may absorb sufficient heat to insure higher temperatures.

As it is impossible to observe the behavior of larvae of other brood stages when they are exposed in the bark to critical temperatures, a series of laboratory tests was carried out with half-grown to full-grown larvae removed from the bark and exposed to varied temperatures of the air. In one test, conditions permitting free circulation were provided by exposing the larvae to currents of warm air in circulation. As a contrast, conditions in which evaporation was reduced to a minimum were provided by sealing the larvae in glass vials and submerging these under water, which was then slowly heated through the range of critical high temperatures. The results of tests are shown in table No. 1, page 15.

Larvae in the sealed containers were killed with the same approximate range of temperatures as those in the outer bark. However, in the open air containers which permitted free evaporation the critical temperatures were 5 - 8 degrees lower and mortality was practically complete at 110° F.[5]

Experiments showed that pupae are somewhat less resistant to cold than larvae, as mortality was practically complete at -5° F. Adults, however appear to be decidedly more susceptible than either larvae or pupae. With them a high mortality results from exposure at 10°, and mortality is complete at -5° F.

The effect of low temperatures upon the insect enemies of the western pine beetle is of importance as it affects their abundance relative to their host. Not much information is available on this point, but the following observations have been made: cermabycid larvae, which destroy some broods of the western pine

Temp. °F.	Effect in open pasteboard containers.	Effect in glass vials sealed with paraffin.
70-90	Normally active	Normally active
90-95	Maximum activity	Maximum activity
95-100	Slightly active; paralysis after prolong exposure	Activity decreases.
100-105	Paralysis after brief exposure; complete mortality after 30 min. exposure at 105°.	Slight activity continues up to 105°.
105-110	Fatal after brief exposure.	Paralysis of larvae occurs after long exposure at 108-110°; larvae recover if returned to normal temp.
110-115	"	Paralysis occurs after 20 min. exposure; larvae to not recover if returned to normal.
115-120	"	Complete mortality occurs after long exposure between 115° to 118°; no larvae survive even brief exposure above 118°.

Table No. I

Results of a test to determine the effect of critical temperatures on the behavior of pine beetle larvae.

beetle by competing with them for space and food, are affected by low temperatures to about the same extent as are the bark beetles. The clerid Enoclerus lecontei, which is the most important insect enemy of the western pine beetle, is not so resistant to cold as is its host. This is relatively unimportant, however, for most of the clerid larvae migrate to the soil at the base of the tree, where they are protected from the low temperatures. From general observations the indications are that the clerid increases in relation to its host in seasons following low temperatures.

From the immediate viewpoint of timber salvage and from the forestry objective of a satisfactory silvicultural management of ponderosa pine stands, one of the first requirements in the solution of the pine beetle problem is a knowledge of what type of tree presents the greatest risk of beetle attack. Once the type of tree most likely to be killed can be recognized with a fair degree of certainty, it is possible to make partial cuttings of beetle-susceptible trees, either for the purpose of salvaging valuable high-risk trees before they are damaged by beetle attack or for the silvicultural objective of reducing mortality and increasing net growth.[6]

During the last decade studies have revealed that the risk of being killed by the western pine beetle is distinctly greater for trees of certain types than it is for other trees in the same stand. In general, the trees more susceptible to attack are the weaker, less vigorous individuals and, to a certain degree, those more advanced in age. The problem, therefore, is one of recognizing the combination of characters which indicates susceptibility.

The various characteristics as recognized by Keen, and divided into four age groups--young, immature, mature and overmature. The characteristics of these age groups in average site IV ponderosa pine stands of the Pacific region are as follows:

1. Young. Age: Usually less than 75 years. D.b.h.: Rarely over 20 inches. Bark: Dark grayish-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 75-150 years. D.b.h.: Rarely over 30 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 upper half of crown.

3. Mature. Age: Approximately 150-300 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 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 and making no further height growth. Branches: Mostly drooping gnarled, or crooked.

In judging the relative vigor of different trees of a given age, the size of crown and abundance of foliage are probably the best outward indicators. Therefore, each age group is further subdivided into four sub-groups based upon relative crown vigor. These are designated by letters A to D as follows:

A. Full, vigorous crowns, with a length of 55 per cent or more of the total height, and of average width or wider; foliage usually dense; position of tree isolated or dominant; diameters large for age.

B. Fair to moderately vigorous crowns with average width or narrower, and length less than 55 per cent of the total height; either short wide crowns or long narrow ones, but neither sparse nor 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.

In order to determine which of these tree classes were particularly favored by the beetles in making their attacks, a study was made in virgin ponderosa pine stands.

The apportionment of beetle-killed trees between the different tree classes as compared with the distribution of these classes in the original stand is shown in the table No. 2, page 20.

The mortality ratio, which has been obtained by dividing the percentage occurrence of beetle losses in a given class by the percentage occurrence of that class in the original stand, gives a measure of relative susceptibility. If, for instance, 9 per cent of the killed trees are found in a certain class, and 9 per cent of the original stand is also found in that class, the ratio will be 1, which indicates no particular preference. Ratios above 1 indicate that such types are more frequently found among the killed trees and are susceptible, while ratios below 1 indicate corresponding resistance.

The relative susceptibility ranking of the different tree classes does not change appreciably under varying conditions. When infestation is low, the selective tendencies are more pronounced and a greater proportion of

Tree Class		Total stand /1000 Acres Trees	%	Trees killed in 4 years /1000 acres trees	%	Average % trees killed /year	Mortality ratio	Rel. susceptibility
	A	1,983	8.8	24	1.5	0.3	0.17	16
1	B	1,160	5.1	40	2.5	0.9	0.49	12
	C	548	2.4	62	3.8	2.8	1.58	5
	D	51	0.2	8	0.5	3.9	2.50	1
	A	1,987	8.8	45	2.8	0.5	0.32	15
2	B	2,181	9.7	153	9.5	1.7	.98	11
	C	1,409	6.3	229	14.1	4.1	2.24	2
	D	344	1.5	29	1.8	2.1	1.20	8
	A	1,940	8.6	56	3.5	0.7	0.41	14
3	B	2,387	10.6	189	11.7	2.9	1.10	10
	C	1,840	8.2	212	13.1	2.9	1.60	4
	D	674	3.0	65	4.0	2.4	1.33	6
	A	1,997	8.9	70	4.3	0.9	0.48	13
4	B	2,242	10.0	188	11.6	2.1	1.16	9
	C	1,290	5.7	200	12.4	3.9	2.18	3
	D	489	2.2	47	2.9	2.4	1.32	7

Table No. II

Relation of beetle-killed trees between the different tree classes as compared with their distribution.

loss occurs in the more susceptible tree classes at the top of the scale. As the mortality rate increases, more tree classes are included. Under severe epidemic conditions, especially on the poorer sites, nearly all classes of trees, except the most resistant types, are apt to sustain a nearly equal proportion of the total loss.

A present study, by Keen, shows that in the ponderosa pine stands of this region bark beetles are carrying on a natural selection which thins the stands of the weaker individuals and favors the survival of the dominants. They are Nature's silvicultural agents, which relieve the pressure of severe tree competition or of critical growth conditions and tend to preserve a natural balance between growing stock and available supplies of plant food and soil moisture. Since all trees with C and D crowns are susceptible to pine-beetle attack, with B crowns intermediate and with A crowns resistant, it is apparent that these beetles are effecting a type of tree elimination which is comparable to an improvement thinning. Year by year they are making "thinnings from below" and a "selection cutting" of the older age classes. On poor sites this elimination during epidemic periods sometimes approaches a clear cutting. This thinning process is largely responsible for the spacing found in a natural forest. The beetles show a marked tendency to concentrate their attacks upon trees growing in groups--

probably because of the severe competition which groupwise trees may experience, especially during periods of drought.

Table No. 3, page 23, shows how the results of this study may be of value in connection with marking ponderosa pine stands for salvage or selection cuttings.

If the primary purpose of a marking is to salvage valuable trees which are likely to be killed before they are reached in the normal course of logging, then only such classes of beetle-susceptible trees as will yield a profit need be included. Trees of no value may be left in the woods to run the risk of beetle attack, for even if they are killed no present convertible value has been lost. On average sites or better, Classes 4C and 3C would be given first consideration. A few of the other C and D crown trees might be taken when accessible. If the site were poorer than average, then trees of Classes 4B and 3B should be included.[6]

Slash has long been recognized, by forest entomologists, as an important source of infestation by the western pine beetle, but reliable quantitative data on the interrelation of slash and insects has been very meager.

A study carried on by the Bureau of Entomology, in southern Oregon, showed that infestations by bark beetles in standing trees in this region, under normal conditions, are 23 attacks and 54 emergences per square foot. In

Tree class	Average diameter (inches)	Average volume (board feet)
Susceptible types, trees of highest beetle risk		
Trees usually of high value		
4C	28	1,280
3C	21	540
Trees usually of low value		
2C	16	160
4D	18	300
3D	14	140
2D	12	70
Unmerchantable		
1C	12	60
1D	10	30
Intermediate types, trees of fair risk under average conditions.		
Trees usually of high value		
4B	32	1,790
3B	26	930
Trees usually of low value		
2B	19	300
Resistant types, trees representing good risks		
Trees usually of high value		
4A	35	2,200
3A	27	1,100
Trees usually of low value		
1B	14	100
2A	20	370
1A	14	100

Table No. III

Value of tree classes in marking trees for salvage or selection cuttings.

the felled trees there was found to be an average of 11 attacks and of 18 emergences per square foot. This data affords evidence of the high relative mortality which attends the breeding of bark beetles in slash, as contrasted with normal broods developing in standing trees.

It is to be seen that the attacks per square foot in the felled timber of the slash numbered slightly less than half of those in the standing trees.

It was found that in the entire slash 1,025 trees had been felled, containing 1,557,690 board feet; of these, 1,048 trees, or 97.5 per cent of the total containing 1,516,730 board feet, or 97.4 per cent of the total content, had been attacked by bark beetles. Of the 1,048 trees attacked, 901, or 86 per cent, containing 1,401,920 board feet, or 92.4 per cent of the total content, were found to have been the breeding places of broods which had emerged. The significance of this high percentage is not, however, so great for most of these broods suffered an abnormally high mortality in the larval and pupal stages, with the result that the new adults which emerged were in the case of many trees fewer in number than the parent adults which entered the slash. This abnormal mortality was caused chiefly by changes in the moisture content of those portions of the tree which constitute the food supply of the developing beetle.[7]

The object of the timber owner is to bring his crop to maturity and successfully harvest and market it. Since forests from their very nature require large investments for long periods the matter of insurance is of paramount importance. Protection is then vital and should include the protection from insects as well as the protection from fire.

In insect control the owner has a natural force which is always at work helping him and includes such enemies of the western pine beetle as parasitic and predaceous insects, mites, bacterial and fungoid diseases, and birds.

One of the most important enemies of the beetles are wood peckers. They will be seen hammering away on the "bug trees" during the fall, winter and spring and succeed in devouring great quantities of the grubs. Sometimes a heavily infested tree is almost stripped of bark by the wood peckers in their search for grubs.

There are also two species of beetles which devour great numbers of the adult pine beetle before they can bore into the bark to protect themselves. One of these, a Clerid, (Thanasimus nigriventris) is a grey beetle about three-eights of an inch long. They may be seen on warm days running actively over the bark of trees which are being attacked by the pine beetles. These predators are attracted to the tree by the attacks of the first beetles, and they seem to have the habit of lying in wait for the beetles as they come to the tree.

During the warm summer days one can see small red or green-bodied insects hovering over infested logs or about infested trees. These are the parasitic flies or wasps, the inchneumon-flies (Ichneumonoidae) and the chalcis-flies (Chalcididae), which light on the bark now and then and move about, carefully examining the cracks and crevices. Finally selecting a favorable spot the insect proceeds to drill a hole through the bark by the use of a long needle-like structure which protrudes from the lower surface of the body near the end. This is known as the ovipositor and is composed of three parts, two of which fit closely together forming a slender tube, within which is the third, needle-like tube, through which the eggs are forced into the cavity under the bark. The females alone possess this long ovipositor. They also possess sensory organs by which they are able to locate the working insects under the bark. When one of these is located the female inserts her ovipositor and by a continual up and down motion of the body drives this needle-like structure through the bark until it enters the insect mine. She then forces one or more eggs into the cavity. The egg hatches into a minute white grub which attaches itself to the larva or grub of the bark-beetle and lives upon the juices of its body. About the time the bark-beetle would normally pupate it dies from the attack of the parasite and upon examining the pupal chamber one will find, instead of the naked pupae of the beetle, an oval, parchment-like cocoon within which the parasite is slowly changing to a wasp. This parasitic wasp will later emerge to deposit eggs in other galleries and destroy other bark-beetles.[8]

Through the operation of what is known as the law of the balance in nature, when the western pine beetle increases and becomes epidemic, their enemies wax fat and prosperous due to increased food supply, until they become so abundant that they outweigh the pine beetles. The pine beetles then are reduced until the predators die off for lack of food, and then the cycle is repeated.

In order to prevent the great destruction of commercial timber, by these beetles, certain methods of control have been devised. But before any of these control methods can be practiced an estimate of the bettle loss must be secured. To do this the forest entomologist relies upon methods which have been developed by the timber cruiser. These vary from a general guess based upon the experience of the estimator to actual mensuration of the timber consisting of the location of land lines by means of compass, the running of sample strips and the measuring and tallying of tree diameters.

Surveys are usually made with one or more of the following objects in view:

1. A general estimate of losses to inform the owner, wither federal or private, of the extent to which insects are affecting his interests.

2. As a basis for formulating control plans and estimating costs of control work.
3. In order to secure data to be used as a basis for scientific studies.

One Hundred Per Cent Cruise.

This method consists in the layout of a definite area, locating, marking and measuring all insect-killed trees that have died within a certain period. This is accomplished by locating the land lines bounding the area. With the aid of a surveyor's compass, strips are run across the area often enough so that every tree of the classes to be marked is brought within a close view of the estimator. The width of strip depends upon the density of the forest type, but as a rule it varies from 4 to 10 chains. The trees are blazed numbered, and mapped, the data being recorded on specially prepared forms. The work is best carried out by means of a special crew of two or three men consisting of one compassman, who runs the one and maps the trees, and one or two "spotters", who mark and number the trees and record the data.

The 100% method is used where accuracy is essential, as in special studies. It is used almost entirely in the marking of infested trees for treatment in control work. The method is necessarily slow and expensive. A crew of three men can cover at best about ½ section per day, at a cost ranging from $20-$40 per section, or from 3-6¢ per acre.

Quite often the information desired does not require an intensive survey and a broad estimate is just as serviceable. In this case, two methods, depending upon the type of forest involved, may be used to obtain the data upon which to base the estimates. The first, topographic viewing is used where the topography is broken so that good view of the timber can be obtained, the trees that can be seen are counted without marking. The estimator gridirons the area by traveling along prominent points and ridges, and from these points counts the visible insect killed trees within a distance of not more than two miles. These trees are spotted on a map. In order to supplement what he has counted, an intensive or 100 per cent cruise is made of carefully selected sample areas of one section or more in area. These sample plots are chosen so as to be representative of the infestation and timbered conditions on the area to be estimated. Inasmuch as the cruiser covers his sample plot extensively first and then intensively, he at once gets a relation between the insect-killed trees he is able to see by topographic viewing, and those actually existing on this sample plot. Thus he may see only 10 insect-killed trees when he covers the plot extensively and finds 30 such trees when he makes the 100% cruise. As an estimate of the total, this ratio of 1 to 3 is then applied to the trees counted on the entire area included in the survey.

From trees marked on the sample plot data is obtained as to average diameters, volumes and proportion of trees killed in each of the two or three years covered by the visible loss. These ratios when determined are also applied to the trees counted on the entire area.

The second method is the sample strip method. At times a forest type is encountered which does not permit the use of the viewing method. Density of stand and level topography may eliminate good view of an area. In this case the estimator falls back upon the sample strip. This consists of following a definite route of travel, such as a road, trail or compass line, and counting all insect-killed trees within a certain distance, usually about four chains on each side of the line of travel. The length of the strip multiplied by its width will amount to a definite area containing the number of trees counted. The ratio of the acreage of this strip to the acreage of the entire area to be estimated can be applied to the number of trees on the strip in order to arrive at the estimate of the total number of trees on the area. This method must also be supplemented by sample plots in order to arrive at the average diameters and volumes of the trees, the proportion of loss for each year and the infesting insects. Where stand and type conditions are uniform this method can be applied with considerable assurance that it will yield fairly dependable results.

It has been found that the estimates obtained from an area by extensive methods do not vary more than 25% from the data obtained by an intensive or 100% cruise of the same area.[9]

In order to prevent the great destruction of commercial timber, by these beetles, and more quickly restore the balance in nature, the Bureau of Entomology has devised certain methods of control.

The two principal methods which have been used to destroy the infesting broods are the burning and the sun-curing methods. These methods are best applied in the late fall, winter or early spring during the period of beetle inactivity. From a study of the beetle it was found that the season of inactivity is approximately from September 15 to April 15 but varies from ten days to two weeks according to the altitude and season.

The Burning Method: The burning method consists of felling the infested trees, peeling the bark from the top half of the log well down on the sides, and as far along the log as it is infested, piling this bark alongside of the log and then burning it. Trees should be felled, when possible, away from standing trees or reproduction. To make a clean job, the limbs are removed, the top lopped off and brought back over the log, the limbs piled on top and all of this debris burned. Late in the spring season when the forest becomes dry it is safer to pile the brush away from the tree and make a fire line around the log. By varying the amount of material left on and around the log, and the width of the fire line, burning can be carried out at any time of the year and during the driest weather with perfect safety. When the bark is wet with snow or rain it is necessary to cut pitch and other dry material to lay along the log in order to get heat enough to insure a good burn.

Small trees, if in groups, are usually cut, bucked up and piled together and the entire pile burned. This is much cheaper than attempting to peel them. In this case, the fire is usually hot enough to consume all of the limbs and main stem. On the larger trees only the bark is burned and the peeled log is simply scorched, and can be used later for lumber provided it is removed from the forest within two years. Trees which have been peeled and scorched do not deteriorate as rapidly as those which are left standing with the bark attached.

<u>The Sun Curing Method</u>: A few years ago the discovery was made, that if bark infested with the western pine beetle was peeled from the trees and laid so as to receive the direct rays of the sun, the beetles would be killed by the excessive temperatures produced.

This method, therefore, gained favor as a summer method of control when the cost of necessary fire precautions became excessive.

In using this method, the attempt is made to fell the trees so that most of the infested trunk is off of the ground. The tree is then limbed and the brush piled at least 10 feet away from the tree so as to give a space in which to spread the bark. All of the infested bark is then peeled and apread on the open ground, (either side up) where it will get the direct rays of the sun for at least two hours during the middle of the day. In case the tree has not been bedded so that all of the underside may be reached in peeling, the log should be rolled so that the bark of the under side may be removed.

However, in the practical application of this method, difficulties were encountered. Slope, exposure, denseness of forest cover, brush, cloudy weather and many other factors made the effectiveness of the method an uncertain quantity, so that, it is no longer used on any extensive scale.

Trap trees as a means of localizing infestation and simplifying control have often been advocated. This method consists of deadening a tree by girdling during the time of flight of the beetles on the assumption that the beetles will gather to in preference to attacking green timber. It is true that the Western pine beetle will come to such trees to a certain extent, but the number of trees required to attract the broods, even in a normal infestation, over the large areas, precludes the use of this method for primary control in Oregon forests. After extensive tests on the San Joaquin project in California, the conclusion has been reached, that "trap trees" fail to trap infestation in sufficient quantity to protect the surrounding forest. Once an area is cleaned, however, the trap-tree method is strongly recommended as a means of keeping the area clean.

Although control through logging has only been used to a very limited extent, it offers the advantage of helping to pay the cost of control through the sale of the salvaged timber.

To destroy the beetles, the infested trees should be either removed to a mill several miles from the forest or the logs placed in the mill pond and left for more than six weeks, or the logs cut into lumber and the slabs burned before the broods emerge.

This method could be applied in many different ways, such as in combination with the sale of a limited amount of green mature timber, with cuttings carried on as a purely control measure during the summer, closing at the beginning of beetle activity. It could only be profitably applied on a unit reasonably close to a saw mill, or where ever the topography does not preclude the use of a portable mill.

The results of recent experiments indicate that it does not pay to attempt to control or reduce normal infestation. The balance in Nature is adjusted to provide for a certain amount of insect loss each year and attempts to avoid this loss may so upset the natural balance as to precipitate an epidemic.

If, however, a careful examination indicates that the beetles are rapidly advancing to or have reached epidemic proportions, then artificial control should be resorted to provided:

1. That the timber values at stake, either from the

commercial, recreational or aesthetic standpoint, warrant the cost of control measures.

2. That the cooperation can be secured, of all owners in the affected territory so that an entire basin or natural topographic unit can be included in the control program.

3. And that control measures can be applied on a scale extensive and thorough enough to insure success, which will require:

(a) That on small, well-isolated areas the entire infestation be treated in one season; or

(b) That on larger units with partial isolation, one season's treatment will be followed by maintenance control or will be logged within three or four years; or

(c) That on large commercial holdings, isolated or not, control work can be accomplished through selective logging and salvage at a very low cost or at a small profit.

To be effective, the control work should remove as near one hundred per cent of the over-wintering infestation within the treated area as is physically possible, and should extend to the natural boundaries of the ponderosa pine type or to one mile or more beyond the edges of the area under protection. Western pine beetle broods from contiguous infested timber can be expected to work back into the treated area at the rate of about one-half mile to each generation or about one mile per year in the central part of its range.[10]

So far wherever artificial control measures have been applied to epidemic infestations they have been successful in reducing the infestation and have helped to restore the balance in nature. Where timber values have been high, the amount of timber saved has more than offset the cost of the work.

Silvicultural management of our ponderosa pine forests should eventually lead to the solution of the present pine beetle problems. Improvement of growth conditions and the reduction of mortality are such closely related phases of timber management that the measures necessary to accomplish one are certain to have a beneficial effect upon the other. The types of trees which should be cut in order to improve growth in the residual stand are also those which should be removed in order to reduce mortality. Although forest management may not eliminate all future bark-beetle troubles, it is at least a step in the right direction of improving the chances of ponderosa pine stands to escape such injury.

In actual practice, economic considerations will often dictate the extent to which silvicultural and bark-beetle hazard-reduction measures may be applied.

On the whole, artificial control work against the western pine beetle can be looked upon as a profitable form of timber insurance.

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