RELATIVE SUSCEPTIBILITY OF PONDEROSA PINES TO BARK-BEETLE ATTACK

BY F. P. KEEN •

ECENT heavy killing of ponderosa
pine in the Pacific states through
attacks of various bark-boring bee-
ties, principally the western pine beetle
(Dendroctonus brevicomis Lec.), has brought to the forefront the important question of con.trolling or eliminating
such losses. In the mature and over-

mature ponderosa pine stands of Califor-nia, Oregon, Washington, and Idaho dur-ing the past two decades, these beetles, collectively referred to as "pine beetles",
have caused an annual timber loss which has run into billions of board feet. Some

areas have lost such high percentages of merchantable stands as to become value-

less for logging. Over many areas the an-nual mortality has so greatly exceeded growth as to resul,t in a serious deple-
tion of mature timber reserves. Such

losses as these raise a serious question as to the feasibility of profitable sustained-yield timber production in the pine re-gion, and discourage private timber oper-ators from leaving any merchantable vol-ume in the woods if it can be profitably liqmdated at the time of logging.
Both from the immediate viewpoint of t•mber salvage and from the forestry ob-jective of a satisfactory silvicultural man-agement 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 great-est risk of beetle attack. Once the type of tree most likely to be killed can be recognized with a fair degree of certainty, it •s possible to make partial cuttings
of beetle-susceptible tres, 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.
During the last decade the relative sus-ceptibility of different types of pondero-sa pine to pine-beetle attack has received considerable study by silviculturists and forest entomologists. These studies have revealed that the risk of being killed by western pine beetles is distinctly greater for trees of certain types than it is for other trees in the same stand. In gen-eral, the trees more susceptible to attack are the weaker, less vigorous individuals and, to a certain degree, those more ad-vanced in age. The problem, therefore, is one of recognizing the combination of characters which indicates susceptibility. Dunning, (2) in the study upon which he based his tree classification, found that in terms of basal area the probable in. sect loss was greatest for his classes 7, 5, and 4; and that in terms of number of trees it was greatest for classes 4, 2, 5, and 7, in that order. Person (4) reached similar conclusions, and found that the beetles showed a decided preference for slow-growing trees, for trees in the diam-eter range between 20 and 30 inches, and for those growing on the poorer sites. This selection, he found, was less marked under decreasing epidemic conditions than under endemic or increasing epidemic
conditions. Further extensive studies made

by the writer from 1927 to 1932, in con-nection with western pine beetle surveys in southern Oregon and northern Cali-fornia, repeatedly showed the same selec-tive tendencies. A preliminary summary

XDivision of Forest Insect Investigations, Bureau U.S. Department of Agriculture.

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of these studies has been reported by
Meyer (3).
During the course of these field studies
it became evident that marked differences

in susceptibility existed within some of
the Dunning tree classes. It even ap-peared probable that, in some cases, these differences might be greater for certain types of trees within a single class than
for different tree classes. In order to

isolate the specific characters that were most important in indicating susceptibility, it seemedesirable, therefore, to set up a more detailed classification, with a large number of small, homogenous, easily recognized tree types, which could be used in the field for further study.

DESCRIPTION OF THE BARK-BEETLE SUSCEPTIBILITY CLASSIFICATION

The tree classification which was

adopted for this purpose, and which may be called the "bark-beetle susceptibility classification", is illustrated in Figure 1. It is based to a large extent upon the same considerations of age, dominance, and vigor which Dunning recognized as forming the basis for his seven classes. The new classification uses these same

basic characteristics to regroup all pon-derosa pines into a larger number of classes. The two characteristics of age and vigor are given primary importance. Four age groups are recognized, desig-nated 1 to 4; and four degrees of crown vigor, designated A to D. Combining these two major groups gives a series of 16 classes, covering all types of trees
found in a stand.

The tree class descriptions toa large extent follow those defined by Dunning, but they have been modified to apply more specifically to the mature ponderosa pine forests of average site IV quality in southeastern Oregon and northeastern California. Although trees throughout the pine region may be similarly grouped into 16 age and vigor classes, the class

descriptions will have to be somewhat modified to apply in other localities and on poorer or better sites.

AGE GROUPS

Trees are first divided into four age groups--young, immature, mature, and overmature. In average site IV pondero-sa pine stands of the Pacific region, the characteristics ofthese age groups are as
follows:

1. YOUNg. Age: Usually less than
75 years. D.b.h.: Rarely over 20 inches. Bark: Dark grayish-brown to black, deep-ly 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 30 inches. Bark: Dark reddish brown, with narrow, smooth plates between the fis-sures. Tops: Usually pointed, but with nodes indistinct. Branches: Mostly up-turned and in whorls for upper half of
crown.

3. MATURE. ,4ge: Approximately 150 .to 300 years. D.b.h.: Rarely over 40 inches. Bark: Light reddish brown with moderately large plates between the fis-sures. Tops: Pyramidal or rounded. Branches: Upturned near top, those of middle crown horizontal, lower ones drooping; whorls incomplete.
4. OVERMATURE. ,4ge: 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 dividing trees into these four gen-eral age groups, more weight should be given to relative maturity, or what might be called "physiological age", than to exact age as indicated by annual rings. Some trees growing under favorable con-ditions, particularly on good sites, retain

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Fig. 1.--A ponderosa pine tree classification chart for comparison of bark.beetle susceptibility classes based on age and vigor.

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their youthful appearance and vigor much
longer than do trees that have been
forced to struggle against unfavorable environmental conditions, such as those
on poor sites. Since trees must be judged
largely on the basis of external appear-ances, those having all the outward char-acteristics of a given age group should be classed in that group, even though they are actually somewhat younger or older than the designated age limits.
The distinction between Groups I and
2 is based largely on color and roughness
of bark. While both are sometimes

called "bull pines" or "blackjacks," only the Group 1 trees have the rough black bark which is so typical of juvenile growth. The change from Group I to Group 2 takes place at approximately 75 years of age in the site IV stands of southern Oregon. At that age there is a slowing down in the rate of height and diameter growth, narrow plates appear between bark fissures, and the bark starts
to take on the reddish-brown color char-

acteristic of maturity. Suppression in the seedling stage may greatly extend the pe-riod of juvenile growth and advance sub-sequent age limits. The distinction be-tween mature and overmature trees, Groups 3 and 4, is more difficult to rec-ognize, and involves character of crown
as well as bark differences.

VIGOR GROUPS

In judging the relative vigor of differ-ent 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.--FulI, 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 (rarely co-

dominant); diameters large for age. B.--Fair to moderately vigorous crowns wi.th 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; diam-eters 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 inter-mediate, 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 inter-mediate; diameters decidedly subnormal, considering age.
By combining the four age sub-groups with the four sub-groups of crown vigor
a total of 16 classes was obtained which

could be analyzed for relative suscep-tibility.
According to definition, the comparison between the expanded classification and Dunning's classification is as follows:

Classes defined Bark-beetle

by Dunning susceptibility classes
1 .... 1A, 2A
'2 .... lB, 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 Dun.ning's
classes

Age group Vigor group
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

RELATIVE SUSCEPTIBILITY OF THE TREE CLASSES

In order to determine which of these

tree classes were particularly favored by the beetles in making their attacks, a

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study was started in 1928 in connection with western pine beetle surveys in vir-gin ponderosa pine stands of southern Oregon and northern Califo•rnia. During a four-year period, 1928 to 1.931, a total of 27,465 beetle-killed trees on approxi-mately 15,000 acres of sample plots were classified under the bark-beetle suscep-tibility classification. During the same perio• amechanically selected sample of 22,428 living trees was similarly clas-sifted for comparison. In 1932 a 10 per cent cruise of the plots was made, and the total number of surviving trees was determined, to which was added the num-ber of trees killed by beetles during the previous four-year period in order to reconstruct the original stand as of 1928. The apportionment of the beetle-killed
trees between the different tree classes

as compared with the distribution of the

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plots during the four-year period was approximately 300 board feet per acre
per year.

The mortality ratios representhe gen-
eral averages found under all of the
above conditions. They should not be considered as fixed constants, but rather as a sliding scale of values which vary
for different stands and intensities of in-

festation. While the present ratios are undoubtedly significant of the general trend in virgin ponderosa pine stands of this region, quite different ratios may be expected in reserve stands left after differ-ent degrees of cutting and in forests placed under management.
On the other hand, the relative suscep-tibility ranking of the different tree classes does not change appreciably un-der varying conditions. When infestation is low, the selective tendencies are more pronounced and a greater proportion of 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 resistantypes, are apt to sustain a nearly equal proportion of the total loss.
It will be noted that in each age group susceptibility increases with a decrease in crown vigor (A to D), except that in the three older age groups the C crowns appear to be more susceptible than the
D crowns. While the number of cases

represented by the D crowns may not be sufficiently large to substantiate this point, it has been observed in the field that the very poorest trees, as represented by the D crowns, are often ignored by the beetles, while neighboring trees of better vigor are taken. It may be that trees
of this class offer too little nourishment to the beetles to make them attractive.

A comparison of the relative suscep-tibility by comparable crown classes for the four age groups brings out the point that there is a gradual increase in risk

with advancing age (1 to 4). It will be noted, however, that the difference in age
between one class and the next is not

nearly so important in determining sus-ceptibility as a difference in crown vigor class. For instance, an old, overmature tree of Class 4A, while more susceptible than younger trees with A crowns, is not nearly as likely to be killed as an imma-
ture tree of Class 2B or 2C. Such a vet-

eran dominant tree usually has crowded
out all of the trees around it and is well

able to continue resisting the elements and insect attacks for a few more years, as it has done for the past three centuries or more. A young intermediate or co-dominant tree struggling for its place in the stand is much more likely to suc-cumb within the same period of time. The present study 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 indl-vid•lals and favors the survival of the

dominants. They are Nature's silvicul-rural agents, which relieve the pressure of severe tree competition or of critical growth conditions and tend to preser•:e 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 effectlug 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 ap-proaches a clear cutting. This thinmug process is largely responsible for the spacing found in a natural forest. The beetles show a marked tendency to con-centrate their attacks upon trees growing in groups--probably because of the severe competition which group-wise trees may

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experience, especially during periods of drought.

APPLICATION TO MARKING PRACTICE

To illustrate how the results of this

study may be of value in connection with marking virgin ponderosa pine stands for salvage or selection cuttings, it may be of interest to examine Table 2, in which the average stand structure on 15,000 acres of site quality IV ponderosa pine in southern Oregon is used as a basis.
In this table the merchantable stand is

subdivided into groups according to rela-tive susceptibility and value.
For practical purposes, the 16 tree classes are arranged in three general sus-ceptibility groups as follows: Susceptible Types.--This group includes all trees with C and D crowns, and, ac-cording to relative risk from higher to

lower, the tree classes belonging here ap-pear in the following order: 1D, 2C, 4C, 3C,. 1C, 3D, 4D, 2D.
Intermediate Types.•This group takes
in trees with B crowns in the three older

age classes. From higher to lower risk in this group, the order is as follows: 4B, 3B, 2B.

Resistant Types.•This group, on the average, is resistant to beetle attack and therefore comprises the best trees to leave in the reserve stand as far as pine-beetle risk is concerned. From the poorest risk to the best, these classes are as follows: lB, 4A, 3A, 2A, 1A. All except class 4A are types of trees which are normally left under present Forest Service marking policy.
In Table 2 trees 10 inches or more in

diameter are arranged by classes accord-
ing to these three susceptibility groups,
and further, according to their relative

TABLE 2
GENERAL SUSCEPTIBILITY AND VALUE GROUPING OF VIRGIN PONDEROSA PINE STAND IN SAMPLE AREA

OF 15,000 ACRES IN SOUTHERN OREGON

Tree class Average diameter Average volume Percentage of stand volume
(inches) (board feet) Tree class Group Type
SUSCEPTIBLE TYPES. TREES OF HIGHEST BEETLE RISK

Trees usually o] high value
4 C 28 1,280 9.1
3 C 21 540 5.3 14.4

Trees usually o] low value
2 C 16 160 1.1 ....
4 D 18 300 1.0 _,_
3 D 14 140 0.5

2 D 12 70 0.1 •i•
Unmerchantable
1 C 12 6.9 0.2

1 D 10 30 .... 0[•

INTERMEDIATE TYPES. TREES

Trees usually o! high value
4 B 32 1,790
3 B 26 930

Trees usually o[low value
2 B 19 300

RESISTANT TYPES.

Trees usually o! high value
4 A 35 2,200
3 A 27 1,100
Trees usually o[low value
1 B 14 100
2 A 20 370
1 A 14 100

OF FAIR RISK UNDER AVERAGE CONDITIONS

23.0 ....
12.4 35.4 ....

3.7 3.7 39.1

TREES REPRESENTING /3OOD RISKS

25.5 ....
11.9 37.4 ....

4.3

1.2 •[• 4•

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commercial value as indicated in a
by Anderson (1) for comparable: t•,,e.e.
classes.

If the primary purpose of a ma'cking
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 in-eluded. Trees of no value may be left in
the woods to run the risk of beetle at-

tack, for even if they are killed no present
convertible value has been lost. On aver-

age sites or better, Classes 4C and 3C,
which in the stand illustrated in Table 2

contain 14.4 per cent of the volume, 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, representing an addi-tional 35.4 per cent of the stand in trees of intermediate risk but of high value,
should be included.

Such a plan of salvage would neces-sitate covering large areas with a light cut in a short space of time. Economic
considerations will decide to what extent

such a plan is feasible and how large a
volume will have to be removed to make

the operation profitable. Unless the cut is heavy enough to open up the stand and stimulate growth in the reserve, the effect in reducing the threat of beetle in-festations is likely to be negligible.
If, on the other hand, the primary pur-pose of a marking is to forestall pine-beetle outbreaks and reduce mortality rates, then all the more susceptible types of trees likely to foster infestationshould be removed and the stands sufficiently thinned to give noticeable release and growth stimulation to .the reserve. This usually will involve a much heavier cut, and it will not be possible to cover an area as quickly as with a salvage cutting. In average site IV stands, the minimum requirement would be the removal of the more susceptible types,' which include all

trees of classes C and D. On poorer than average sites, trees of intermediate risk, the older trees with B crowns, would also need to be taken.

While it seems reasonable to suppose
that a stand which has been thinned of

the more susceptible trees should be in better shape to resist bark-beetle epi-demics, there is no proof as yet that such
stands will be immune to further losses.

During periods of bark-beetle epidemics trees of all classes may be killed, with little regard to apparent vigor. Also, on poor sites, in "fringe type" timber, and on areas suffering from the effects of drought, all types of trees are reduced in vigor and resistance to pine-beetle at-tack, and tend to become nearly equal in •susceptibility. There are many examples to show that on such problem areas it is futile to leave as a reserve any but the youngest .and most vigorous trees.
It will be noted that the marking sug-gested for the purpose of l•reventing beetle outbreaks is comparable to present marking practice in the ponderosa pine
forests of the National Forests and Indian

reservations of this region. Under this more or less standard system, all of the more susceptible and intermediate types of trees (Table 2) are marked for cut-ting, as well as beetle-resistant trees of Class 4A. A cutting under this system removes approximately 80 to 85 per cent of the stand and so nearly eliminates all types of beetle-suscel•tible trees on the area cut over that the problems of salvag-ing additional values or of further reduc-ing the threat of beetle loss are usually solved. During the last decade, however, on poor sites and in fringe-type timber,
the beetle losses to reserve stands cut

under this marking practice have been
such as to raise consi.derable doubt as to

ß its adequ. acy under these conditions. The cutting of all merchantable timber, such as is the practice on many private operations, of course eliminates for a good many years further trouble from' the

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western pine beetle. Such cuttings, if ard-reduction measures may be applied. protected from fire, produce even-aged Because of their low commercial values, stands, often with satisfactory stocking,' it will often not be feasible to remove but with the prospect of a second timber all of the small beetle-susceptiblerees crop projected far into the future. For' which it might be desirable tocut from certain problem areas, such as those .a strictly entomological standpoint. The mentioned above, a heavy cut is undoubt-
edly the only practical method of dim-
•nating serious beetle losses in reserve
stands and of obtaining substantial net
annual growth.
Silvicultural management of our pon-derosa pine forests should eventually lead to the solution of the present pine-beetle problems. Improvement of growth

final solution of an• marking problem will of necessity be determined by weigh-ing the importance of growth, mortality,
and economic factors, keeping always in
mind the ultimate objective of continuous
profitable forest production.

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conditions and the reduction of mortality

are such closely related phases oftimber 1. Anderson, I. V. 1934. Why selective management thathe measures necessary cutting of ponderosa pine pays. The 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 •s at least a step in the right direction of improving the chances of ponderosa pine stands to escape such injury.
In actual practice, economic consider-
at•ons will often dictate the extent to which silvicultural and bark.beetle haz-

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