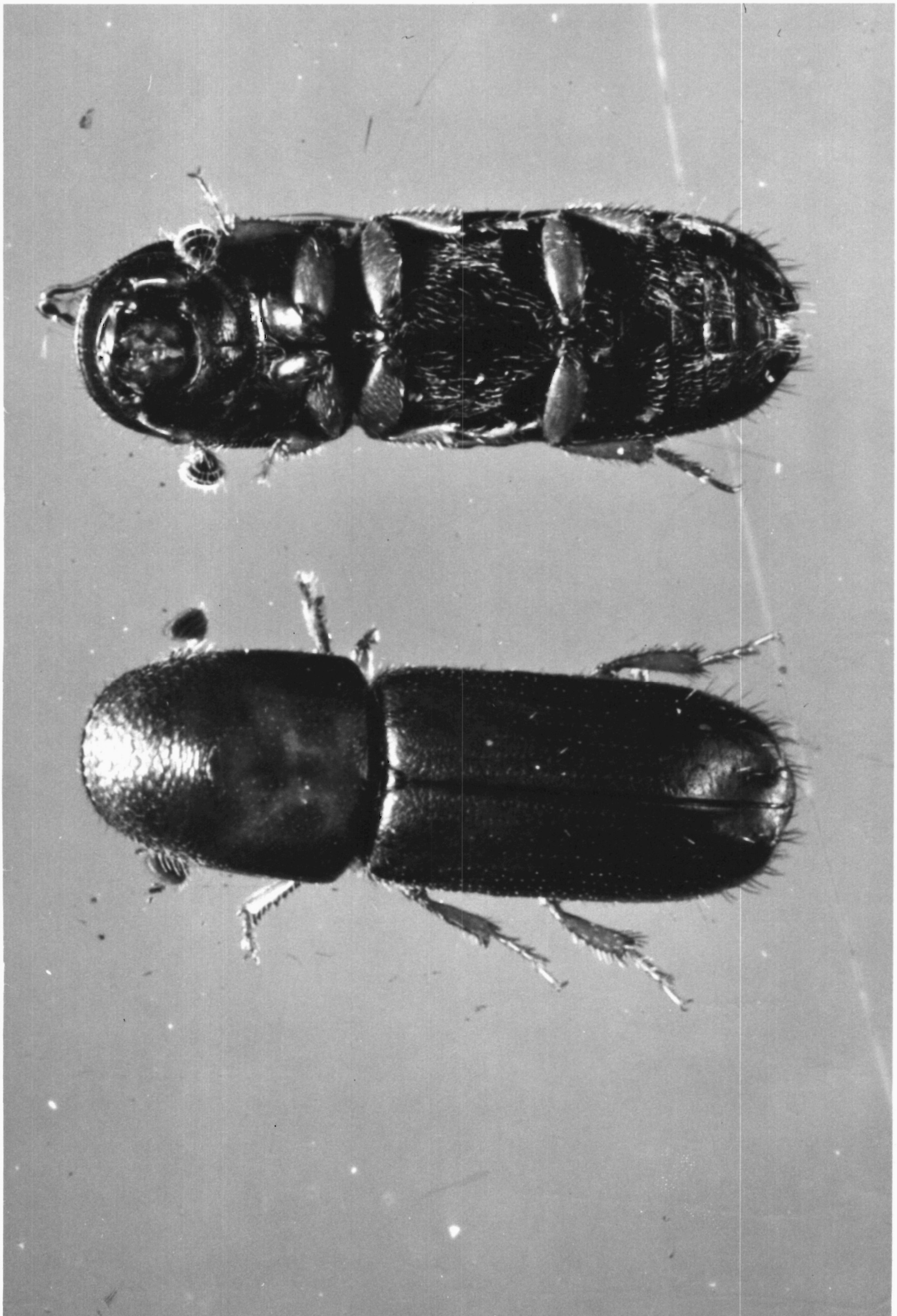
PLATE 11

Dorsal and ventral view of *Gnathotrichus sulcatus*.

Compare the length of the tarsi with those of *Platypus*.

X 34



The hood or pronotum is quite roughened on the anterior half. A transverse somewhat lunar ridge is located just anterior of the halfway mark. Behind this ridge the pronotum is shiny and quite smooth though it is punctured. The elytra are smooth and shining with sides parallel for two-thirds of their length. They are lined with parallel lines of shallow punctures. The elytral declivity is indented slightly and is equipped with a row of small projections or teeth on each side of the indentation. These projections seem to be more prominent in some specimens than in others. The legs are well-developed with the front legs having large contiguous coxae. The tibiae are widened and strongly compressed with serations on the inner margins and prominent teeth near the apex. All parts of the body that do not come directly in contact with the walls of the galleries are sparsely covered with long, somewhat reddish hairs. The two species of Gnathotrichus attacking coniferous wood in the Douglas-fir region can be separated after a little practice.

In Gnathotrichus retusus the frons is not aciculated except at the very tip just above the mandibles. The sutures of the antennal club are straight or slightly curved. The tibia has three marginal teeth and the pregula protrudes anterioventrally. The small projections on the elytral declivity seem to be more pronounced in this species also.

In Gnathotrichus sulcatus the frons or front part of the head appears to have been scratched (aciculate) with a fine needle in a fan-shaped pattern. The sutures of the antennal club are moderately to strongly curved; the fore tibia has two submarginal teeth and the underside of the head is without a protrusion (pregula) at the suture (gular suture).

At least for one not familiar with these insects, the above-mentioned characters may be hard to locate. If the two species are compared with one another they are quite easily separated and afterwards determination is not a problem.

Gnathotrichus retusus (LeConte)

These beetles are from 3.4 to 3.8 mm long. They are dark reddish brown with lighter color on the pronotum and at the base of the elytra. All the characters listed above in separating this species from G. sulcatus apply here also.

The sexes are very difficult to separate.

Blackman (2, p. 270) says that the female can be distinguished from the male by the longer hairs on the antennae. Swaine (59, p. 91) found that the male has the front of the head finely and feebly aciculate (appeared to have been scratched by the point of a needle) above the mandibles. The eggs and larvae are similar to those of all Scolytidae. The eggs are very small, round to elongate, and white. The larvae are legless; the head is distinct and equipped with large mandibles. The body is deeply wrinkled, white or yellowish and somewhat hairy. The pupae are white, later becoming yellowish. The antennae wing pads and legs are plainly visible on the fully formed pupae (Plate No. 2).

Distribution: British Columbia south to California, east to Nevada and South Dakota.

Hosts: Pinus ponderosa, P. contorta, P. jeffreyi, P. radiata, P. monticola, P. lambertiana, Abies grandis, A. magnifica, Pseudotsuga taxifolia, Tsuga heterophylla, T. mertensiana, Picea sitchensis and probably other conifers. The host files at the Pacific Northwest Forest and Range Experiment Station in Portland, Oregon list Quercus kelloggii as a host, also.

Work and Habits: These beetles, like most ambrosia beetles, attack injured, dying and recently-dead trees, logs, stumps and limbs. Occasionally they will work in apparently healthy trees. Usually these beetles work only in the sapwood, but they occasionally mine the heartwood in such woods as hemlock and fir. After boring directly into the wood from one to three or more inches the galleries branch and more or less follow the annual rings (Plates No. 1 and 12). The eggs are laid in niches along the galleries, and the larvae, as they develop, mine out a larval cradle which is about the size of the adult beetle (Plate No. 4).

The galleries are about .052 inch in diameter. The boring dust differs from that of Platypus wilsoni in that it superficially appears granular or "corn-mean" like. When viewed under magnification the individual wood particles are small curved chips. The boring dust of the genus Trypodendron appears similar to that of Gnathotrichus but when viewed under magnification the particles are not curved.

Gnathotrichus sulcatus LeConte

Gnathotrichus sulcatus is very similar to G. retusus except for those characters listed previously in separating the two species. These are, principally, the convergently aciculated frons, the gular region not produced anteriorly, only two submarginal teeth on the fore tibia and the less pronounced teeth or denticles on the elytral declivity. For a detailed description of this species and G. retusus one should consult Blackman (2) and Shedl (56).

Distribution: British Columbia to New Mexico.

Hosts: According to Chamberlin (9, p. 331), Gnathotrichus sulcatus probably attacks all conifers within its range with the probable exception of Taxus. It is definitely known to attack Pinus ponderosa, P. monticola, P. contorta, Picea sitchensis, P. engelmanni, Tsuga heterophylla, T. mertensiana, Pseudotsuga taxifolia (now P. menziesii Mirb. Franco), Abies concolor, A. grandis, A. magnifica, Thuja plicata, Sequoia sempervirens and S. gigantea. The author has also collected specimens from Prunus emarginata (Dougl.) Dietr., Abies amabilis (Dougl.) Forbes, Abies procera Rehd., and Castanopsis chrysophylla (Hook.) DC.

Habits and Work: The habits and work, so far as is known, are similar to those listed for Gnathotrichus retusus.

Prebble (54, pp. 48-54) reports that in British

PLATE 12

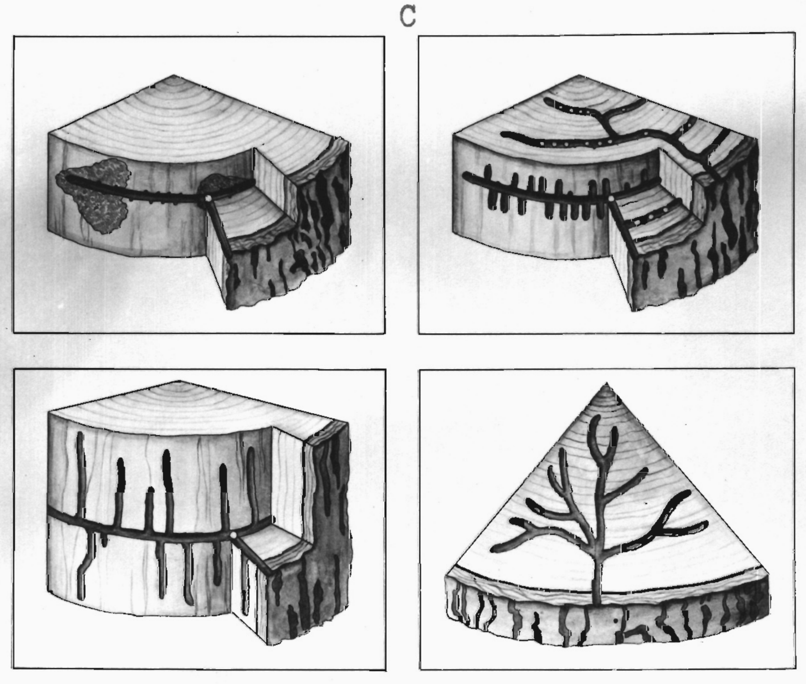
A and B are galleries of _Gnathotrichus spp._ C is a schematic drawing showing some of the types of galleries constructed by various genera of ambrosia beetles. The upper right drawing of C shows a typical _Trypodendron_ gallery.

PLATE 12

A

B

C



"U.S. Forest Service Photo"

Courtesy Pacific Northwest Forest and Range Exp. Sta.

Columbia, *Gnathotrichus sulcatus* is much more prevalent than *G. retusus*. Concerning *G. sulcatus* he says that they emerge in May or June to attack new hosts. In late summer or early fall there is a second period of attack. Both species are reported to attack very fresh logs and penetration of five to six inches is not unusual.

Doane and Gilliland (16, pp. 915-921) did some work with the Douglas-fir ambrosia beetle (*G. sulcatus*). They found that in standing dead timber these beetles first attacked the tops and later the lower bole and stumps where they may have several generations. In silver fir killed by the balsam woolly aphid (*Adelges piceae* Ratz.) this species attacks first at the base of the tree with the upper portion of the bole only sparsely attacked unless the tree is on the ground.

These same authors found that the entrance and part of the main gallery is constructed by the males; the females excavate the brood galleries. Copulation takes place in the main and secondary galleries. The eggs are laid immediately after copulation in small niches constructed by the females. These niches are just large enough to hold the egg and after the egg is laid it is sealed off with a plug of boring dust. The eggs hatch in seven to eight days and the larvae devour the ripe conidia that arise from the fungi that is growing on the walls of the egg niches and the plug of frass and excrement. The larvae keep enlarging the larval galleries or cradles until they are full grown at which time they reverse their position and pupate. The male adult usually is found at the entrance of the main tunnel with his body blocking off the gallery from enemies. Doane and Gilliland determined the fungus associated with G. sulcatus as a species of Ceratostamella.

Genus Trypodendron Stephens

Members of the genus Trypodendron are easily separated from other ambrosia beetles by their short, stubby appearance, roundish pronotum, which is nearly as long as the abdomen, the smooth, shining body and the divided eyes. The antennal club is large and entire (without sutures). The elytral declivity is neither excavated nor armed. The sexes are of approximately the same size and appearance except that the males have the front of the head deeply excavated (Plate No. 13). The only other genus of ambrosia beetles with divided eyes is Xyloterinus which contains a single species that is distributed along the coast of eastern United States and Canada.

The galleries of *Trypodendron* are similar to those of *Gnathotrichus* in that they penetrate directly through the bark into the sapwood where they usually branch from one to several times. The young are reared in separate cradles similar to *Gnathotrichus*. The diameter of the galleries made by *Trypodendron* are larger than those made either by *Platypus* or *Gnathotrichus*.

Unlike other genera of ambrosia beetles, the members of the genus *Trypodendron* do not spend the winter in the galleries but rather are thought to hibernate in the duff of the forest floor (11, pp. 3-4, 52, p. 3 and 55, p. 48).

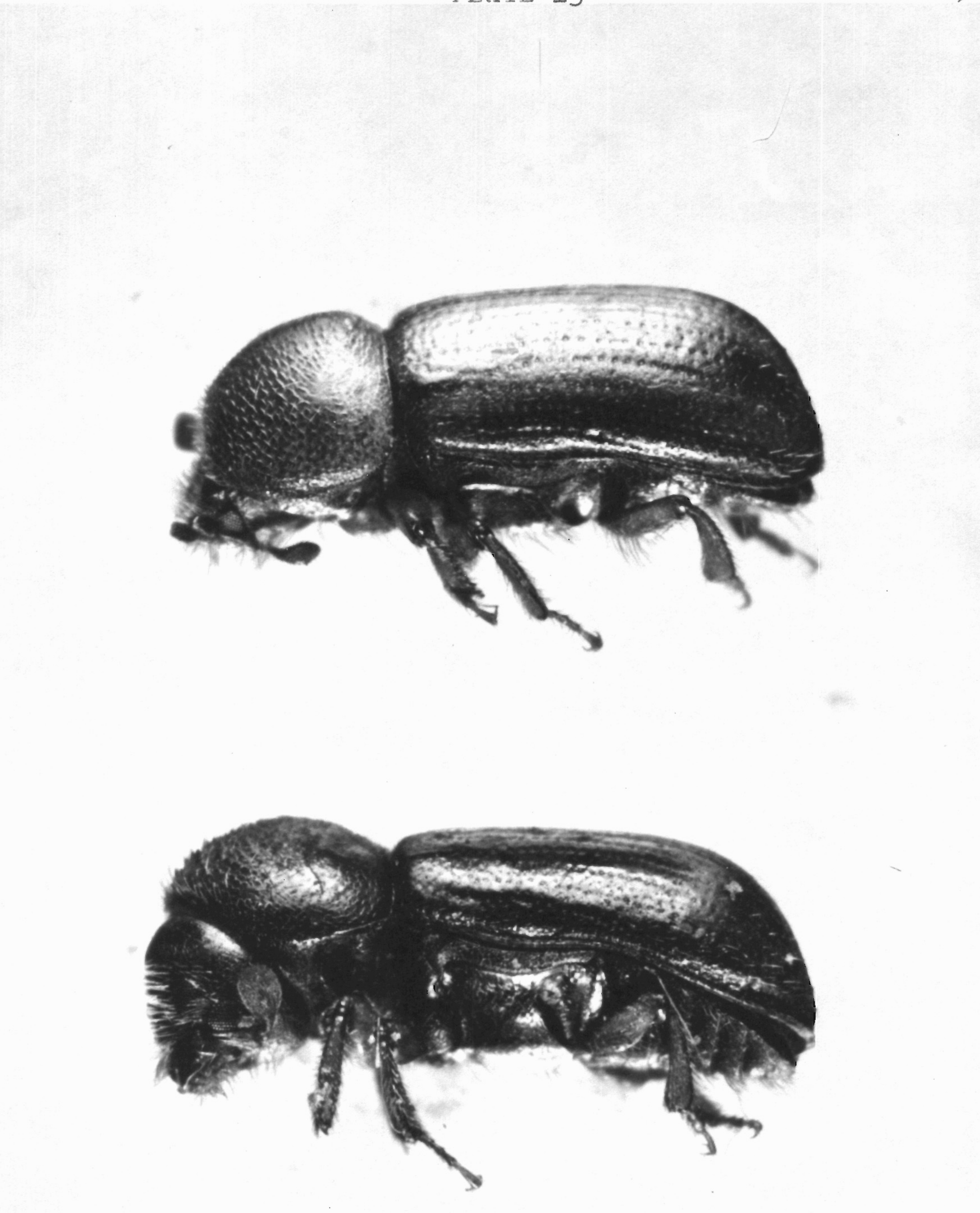
Chapman (11, pp. 3-4) found that in the spring as many as 33 per cent of the attacking females were from previous broods. In the latter part of the summer approximately the same proportions of old adult females go into hibernation in the duff of the forest floor. This indicates that the adult beetles live for a considerable period of time. The method Chapman used to separate the young females from the old was quite involved but interesting. The condition and appearance of the seminal receptacle, ovaries and associated glands all help in determinations, but the presence of small structures, the corpora lutea, are the main items of

PLATE 13

This plate shows male (top) and female _Trypodendron_. Note the concave or flattened head of the male.

X 29

PLATE 13



distinction. A corpus luteum is a firm reddish-yellow substance formed in the follicle or sac after it has ruptured in discharge of an ovum. It is here the ovum matures. Although he found no consistent signs of wear on the external anatomy of the beetles, hairs on their head are frequently missing. Investigations are still being carried out to correlate reproductive organ changes with adult history in the male.

Kinghorn and Chapman (46, p. 3) have made some interesting observations on the flight habits of Trypodendron species. These authors made their observations at Cowichan Lake, Vancouver Island, on May 6, 7 and 8, 1954.

> The flights coincided with a rise in maximum air temperature from 57-59 degrees Fahrenheit or less, during the preceding weeks to 67-69 degrees F. for the period of flight. Prior to the dates mentioned, these insects were rarely seen in the area. The beetles were observed on a clear-cut area in which the western hemlock and Douglas-fir had been felled the previous fall. Maximum numbers were seen between 2:00 and 6:00 p.m. The beetles flew mostly within a few feet of the ground and because of their numbers resembled light swarms of midges or ants. Their flight differed, however, in that the beetles flew in a fairly consistent direction and showed no tendency to circle or remain over the same object. The insects were abundant on the logs, stumps and slash in the area. The numbers on different logs varied greatly, however, and this difference was evident in the number of subsequent attacks. The beetles did not enter the bark immediately, but usually spent some time walking over the

surface before commencing to bore, usually in a bark crevice. They were frequently seen to take flight again from apparently attractive logs. Mating of the beetles was repeatedly observed to take place on the bark. The beetles readily alighted on dark clothing, but not on white canvas. Although other scolytids of various genera were observed in flight, no other ambrosia beetles were noted at the time. Several flights were noted during the subsequent weeks, but none compared in density with the initial attack period.

There is some controversy concerning the specific classification of the genus *Trypodendron*. In the past, four species have been recognized that attack coniferous timber in the Douglas-fir region. These are: *Trypodendron lineatum*[2] Oliver, *T. cavifrons* Mann., *T. ponderosae* Swaine and *T. rufitarsis* Kirby.

Swaine (59, p. 85) uses the striations of the elytra and the pale band on the pronotum as identifying characteristics. Concerning the separation of this genus into species, Swaine (58, p. 22) says that *T. ponderosae* is very closely allied to *T. rufitarsis* which, in turn, is so closely allied to *T. lineatum* that it has been long considered a synonym. As for *T. cavifrons*, Swaine (59, p. 85) says that it is apparently distinct from *T. lineatum* but there are confusing variations.

[2]*Trypodendron lineatum* Oliver is also quite frequently referred to as *T. bivittatum* Kirby.

Dr. Chamberlin is of the opinion that of the above-mentioned species, only *T. lineatum* and *T. rufitarsis* are true species.[3]

Because of the great difficulty or impossibility of separating the species of *Trypodendron* as they exist presently, it seems advisable for the purpose of this paper to consider the genus as consisting of two species which attack conifers in the Pacific Northwest rather than four.

Trypodendron lineatum may be separated from *T. rufitarsis* as follows:

1. Interspace (the raised portions of the wing covers between the lines or striations) 2 of the declivity (posterior sloping portion of elytra) as wide as interspace 1 and 3 and punctured; the elytra and pronotum normally marked with pale bands.------*T. lineatum* Oliver

1a. Interspace 2 very narrow and not punctured; the pronotum and elytra without pale bands, but with an obscure, smokey reddish median area.----------------------*T. rufitarsis* Kirby

Trypodendron lineatum Oliver

This species, like other members of the genus is quite stubby in appearance. It is 3.25 mm to 3.5 mm in

[3]Interview with Dr. W. J. Chamberlin, Associate Professor of Entomology, Oregon State College, May 14, 1956.

length and is about two and one-half times as long as wide. It has divided eyes and an antennal club without sutures. The color of these insects is quite variable. Some specimens may be wholly black, others may be smokey black or greyish. Many have two light yellowish-orange or piceous stripes running parallel along the elytra or outer wings. In some specimens the pronotum may be entirely black, black with a piceous basal stripe, or almost entirely piceous or light colored. Like most ambrosia beetles the body is sparsely clothed with long reddish hairs on the portions that do not continually come in contact with the gallery walls.

Distribution: Chamberlin (9, p. 301) gives the distribution of this species as widely distributed in the United States and Canada.

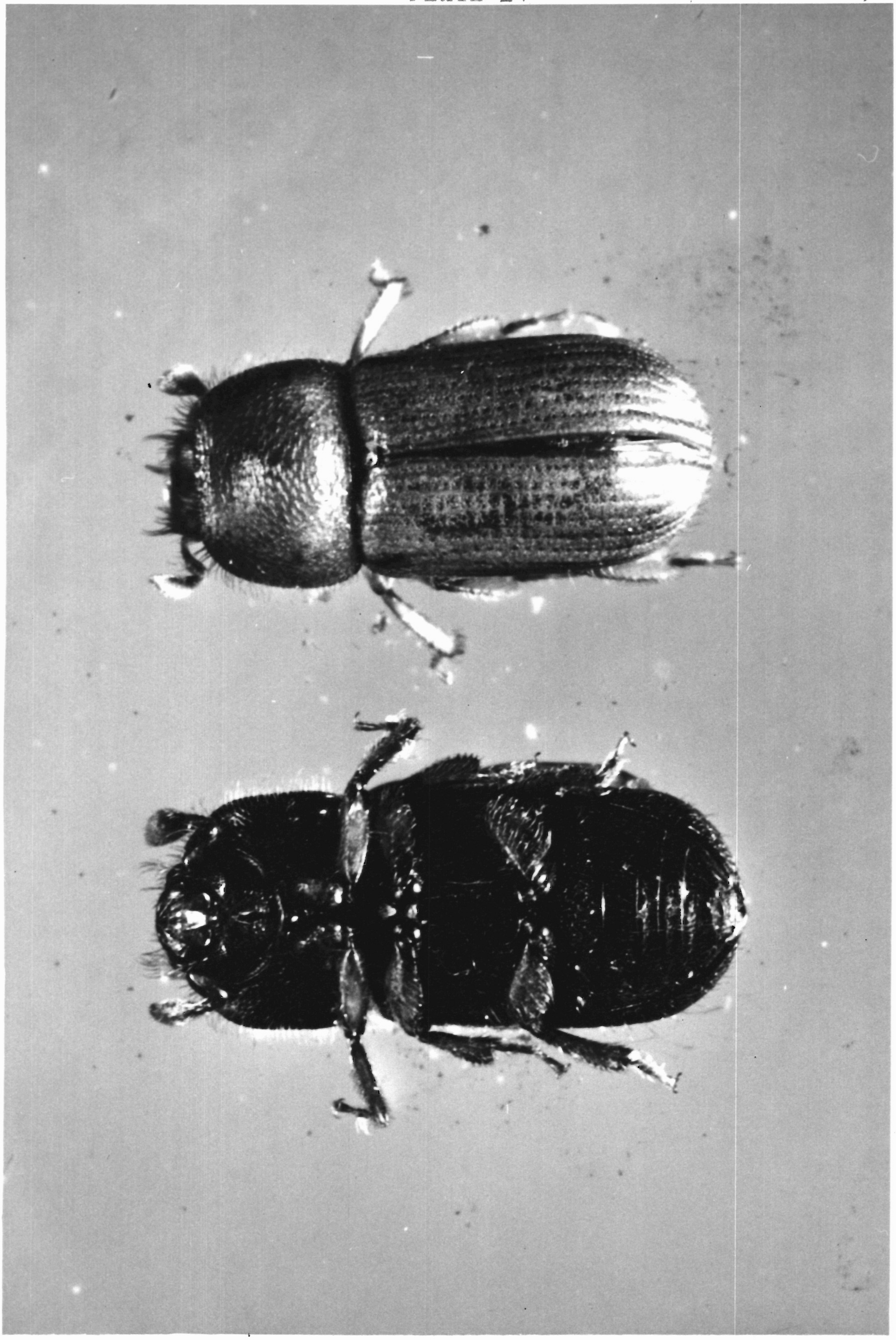
Hosts: This species probably attacks almost all conifers within its range. It has been reported to attack *Abies*, *Picea*, *Pseudotsuga*, *Larix*, *Pinus*, *Tsuga*, *Sequoia* and *Juniperus*. During the field work for this paper *T. lineatum* was found quite abundantly in *Thuja plicata*. The host files at the Pacific Northwest Forest and Range Experiment Station in Portland, Oregon, list

PLATE 14

Dorsal and ventral views of *Trypodendron lineatum*.

Notice the light color of the upper specimen. This is a very young or callow adult.

X 29



this species as attacking *Alnus rubra*. *T. cavifrons* has been reported from *Populus trichocarpa*.

Habits and Work: *Trypodendron cavifrons* is listed as the most common and destructive species of ambrosia beetle in British Columbia (52, p. 2, 55, p. 34 and 28, p. 2). *Trypodendron cavifrons* has been separated from *T. lineatum* by having the punctures of the elytra rather deep and the pale band of the pronotum usually extending from the base to the forward margin. This is opposed to the supposedly shallow punctures and basal band in *T. lineatum*. If these should be distinct species the above-mentioned points of separation are so vague that very few persons could separate them. Therefore, for the purposes of this paper which is meant to be of practical use to foresters as well as forest entomologists, *T. lineatum* Oliver and *T. cavifrons* Mannerheim will be considered together as will *T. rufitarsis* Kirby and *T. ponderosae* Swaine.[4]

Concerning the habits of this species, Prebble (55, p. 34 and pp. 48-50) says that attacks are made as early as April and the beetles penetrate quickly into the

[4] ibid.

sapwood for one or two inches. From one to several side galleries are constructed and eggs are laid in small pockets along these side galleries. Development is rapid and the beetles leave by the latter part of the summer or early fall to overwinter in the duff of the forest floor.

In the old growth Douglas-fir, galleries seldom penetrate more than one inch while in young growth Douglas-fir, true firs and hemlock penetration to depths of four to five inches is quite common (55, p. 48).

In an experiment designed to determine a damage index by which one could figure the amount of affected lumber from the number of holes on the surface of the log, Graham and Richmond (28, p. 3) found that in western hemlock, 98 per cent of the galleries of this species were in the outer two and one half inches. In Douglas-fir all galleries were in the outer inch and a half. In this same experiment the number of holes on the radial surface of sawn lumber was correlated with the number of holes on the log surface. They found a high correlation between these two variables. In hemlock there were 240 holes per 1000 linear feet of radial face of lumber cut for each hole per square foot of log surface. In Douglas-fir this figure was 220 holes per 1000 linear feet. The correlation coefficients were 0.694 and 0.827 for hemlock and Douglas-fir respectively. One hole in the log surface may result in many on a radial face (Plate No. 1).

McMullan (52, p. 37) and Graham (27, pp. 101-102) say that in Canada this species is the worst offender because it attacks in the greatest numbers. One hundred to 200 attacks per square foot are not uncommon. Individually the members of the genus _Trypodendron_ do not cause as much damage as they do not generally penetrate as deeply as either _Gnathotrichus_ or _Platypus_. One of the reasons for this is because the species of the latter two genera may remain in the logs for several years (44, p. 22).

Trypodendron species seem to prefer partly seasoned wood rather than very fresh wood (52, p. 34, 53, p. 245, 55, p. 49 and 23, p. 8).

The larvae are raised in the larval cradles throughout their entire lives as in the genus _Gnathotrichus_. During the field work for this problem it was also found that the galleries of _Trypodendron_ were much more heavily stained black by fungus action than were either _Gnathotrichus_ or _Platypus_. One of the reasons for this is because _Trypodendron_ leave the logs after one attack and the fungus quickly grows throughout the galleries, whereas _Gnathotrichus_ and _Platypus_ remain in the logs longer and keep the fungus gardens cropped. This difference in staining may also be due to the species of fungi.

Trypodendron rufitarsis Kirby

In the past Trypodendron ponderosae Swaine has been considered a distinct species. It was separated by having the striae strongly impressed on the elytral declivity with the second interspace depressed and the punctures small. These points of separation were opposed to the striae shallow, the second interspace only slightly depressed and the punctures rather coarse in Trypodendron rufitarsis. For the same reasons listed under the lineatum--cavifrons section these species will be considered together.

Description: Even this species is very similar to T. lineatum. The separating characteristics are given in the key at the beginning of the section on this genus. The main characteristics are that in the rufitarsis--ponderosae group interspace two of the elytral declivity is very narrow and not punctured and the pronotum and elytra are without pale bands. In the lineatum--cavifrons group the second interspace is as wide as interspace one and three and is punctured. The elytra and pronotum normally are marked with pale bands.

In addition to the above characteristics, Chamberlin (9, p. 302) says that the female is similar in size and shape to *lineatum*, but the elytra are distinctly narrower towards the base and wider behind the middle. The front of the head is more sparsely but more coarsely granulate. The elytral striae are very narrow, slightly impressed with the interspaces flat and punctures sparse.

Distribution: *T. ponderosae* has been listed as occurring from British Columbia south to California. *T. rufitarsis* is listed as occurring from western Ontario to northern Manitoba and throughout the northern states of the United States.

Hosts: *Trypodendron ponderosae* has been listed as attacking *Abies grandis*, *Abies amabilis*, *Pinus ponderosa*, *Tsuga mertensiana* and *Pseudotsuga taxifolia*.

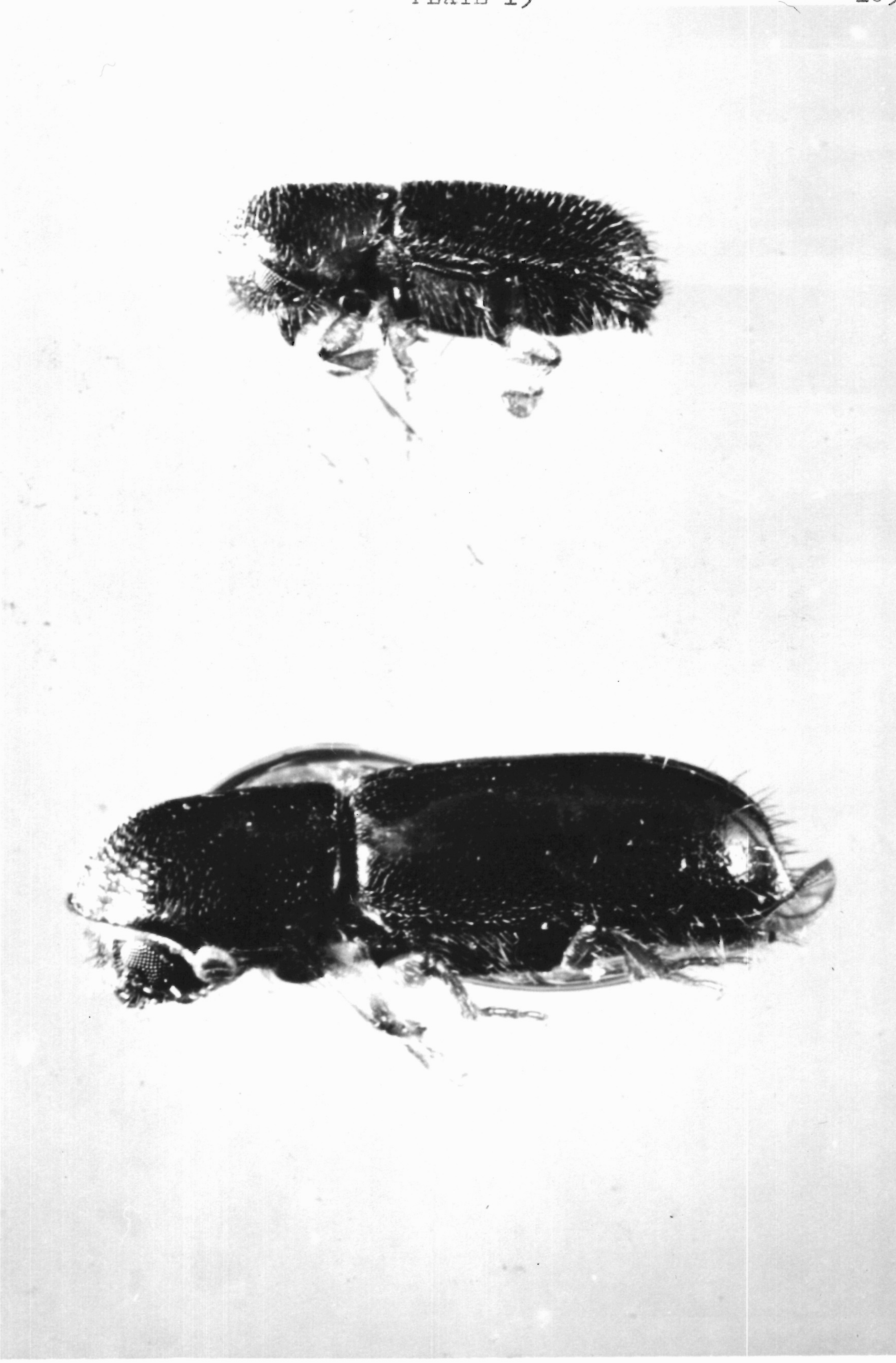
T. rufitarsis is listed as attacking *Abies magnifica*, *Pinus contorta*, *P. resinosa*, *P. monticola* and *Picea spp*.

Habits and Work: Chamberlin (9, p. 302) says that the habits and work of *T. rufitarsis* are similar to *T. lineatum*.

PLATE 15

This plate is designed to show the size differentiation between the genus *Xyleborus* and *Gnathotrichus*. *Xyleborus* resembles *Gnathotrichus* more closely than the other genera covered in this paper. Notice the abundance of hair on the elytra and pronotum of *Xyleborus*.

X 35



Genus *Xyleborus* Eichhoff

There has been much confusion concerning the beetles belonging to this genus and closely-related genera. The genus *Xyleborinus* Reitter has been separated from *Xyleborus*, but according to Dr. Chamberlin[5], the genus *Xyleborinus* no longer exists and the two species of ambrosia beetles previously listed under this genus which attack conifers in the Pacific Northwest have both been placed as synonyms of *Xyleborus sexeseni* Ratz. These two species were previously known as *Xyleborinus tsugae* Swaine and *Xyleborinus libocedri* Swaine. Chamberlin (9, p. 456) says that these beetles are apparently rare and of little or no economic importance. Prebble (55, p. 54) says that *Xyleborinus tsugae* is not abundant in Canada and when present seldom penetrates more than two inches into the sapwood.

Xyleborus saxeseni Ratzburg

The members of this species are considerably smaller than any of the previously-mentioned ambrosia

[5] ibid.

beetles. There is sexual dimorphism with the female the greater in size. The female is from 2.0 to 2.5 mm long and the male 1.5 mm. The females are blackish or brown, shiny and thinly clothed with pale pubescence. The elytra are feebly punctate-striate. The male, in addition to being shorter, is clothed with longer pubescence (Plate No. 15).

Distribution: Eastern and western United States and Europe.

Hosts: *Tsuga heterophylla*, *Libocedrus decurrens* Torr. and many hardwoods. Prebble (55, p. 54) says that *Xyleborinus tsugae* also attacks Douglas-fir.

> Habits and Work: The tunnel is a distinct cave affair and the young are free to roam about. The entire surface of the walls of this chamber is plastered with ambrosia fungus, consisting of short, erect stems terminating in spherical conidia. When fresh, the fungus is colorless, but usually is greenish yellow, resembling sublimed sulphur. The brood chamber is packed at times with eggs, larvae, pupae and adults. The larvae aid in extending the chamber. The wood passes through their bodies, and great quantities of mustard-yellow excrement is ejected from the colony, but a portion is retained within the cave to form a bed for new crops of food fungus. Sometimes the remains of deceased members are found in a deep recess with the mutilated remains of predatory beetles (9, p. 457).

The tunnels of *Xyleborus sexeseni* are .8 to .9 mm in diameter (36, pp. 21-29). This would be equivalent to .0335 inch as compared to .0520 inch in those tunnels constructed by *Gnathotrichus*.

A STUDY OF AMBROSIA BEETLE INFESTATION OF DOWN CONIFEROUS TIMBER IN BENTON COUNTY OREGON

This study was designed primarily to determine the frequency and intensity of ambrosia beetle attacks in the logs of various coniferous tree species in Benton County, Oregon. Answers to the following questions were sought:

1. What percentage of the logs are likely to be attacked after being exposed to ambrosia beetles for at least one summer?

2. What are the relative intensities of attack for each genus of beetle?

3. What tree species is most susceptible to ambrosia beetle attack?

4. Do each of the genera show any preference for a particular tree species?

5. Does the diameter of the log and thickness of bark play any part in the number of attacks?

6. Is there any relationship between the number of entrance holes per square foot of log surface and the length of time the logs have been on the ground?

7. Does the orientation or position of the log play any part in attack intensity?

Other pertinent and interesting information observed during the field work of this thesis is included.

Observations are confined to those genera and species of ambrosia beetles that attack coniferous trees in Benton County, Oregon. These same species occur throughout most of the Douglas-fir region. The habits of these ambrosia beetles are probably quite similar elsewhere, but they may vary considerably from year to year or from area to area.

This study is primarily economic rather than biological. Although a study of the biologies of these insects may be basic, it is felt that this survey, which is designed to determine the frequency of ambrosia beetle attack, is a necessary prerequisite to a damage and control study.

Description of Study Area

All data were taken from cull logs and large chunks of wood left after logging. The logging settings are located on Mary's Peak which is about 12 miles west of Corvallis, Oregon. The area studied is on the east slope of the mountain and is within the Corvallis watershed which is carefully managed by the United States Forest Service.

The predominant timber species on the area is Douglas-fir. At the higher elevations, western hemlock is often found in mixtures with Douglas-fir, while at the lower elevations grand fir is the main associate. Western red-cedar occurs as a monor component of the stand over the entire slope, but is more prevalent along the streams and in other moist areas. Pacific yew (Taxus brevifolia Nutt.) is present as small, scattered trees. Red alder (Alnus rubra Bong.) and golden chinquapin (Castanopsis chrysophylla Hook. DC.) are the predominant broadleaf trees of any size. Oregon white oak (Quercus garryana Dougl.) and bigleaf maple (Acer macrophyllum Pursh.) occur at lower elevations. All of the above mentioned hardwood species are attacked by ambrosia beetles.

The elevation range of the clear-cut units is from 700 to 2600 feet. The units are from 2 to 20 acres and are on slopes from 0 to 90 per cent. The annual precipitation is around 50 inches and at the higher elevations is mostly in the form of snow.

The Douglas-fir Site Class ranges from high Site III to Site V with the average a middle III. The average Douglas-fir is around 30 inches d.b.h. and the average yield per acre is about 70 thousand board feet.

Techniques of Gathering Data

Sixteen logging settings were inspected in the Corvallis watershed on Mary's Peak. The majority of these settings had been burned, thus limiting the size of the sample area to a few, scattered spots. An especially thorough job of logging was done in this area and only small chunks and cull logs were left to sample. The sample was further limited to those pieces that most nearly approached merchantable log size. With these limitations many settings had only a few logs suitable for sampling. In some settings all suitable logs were sampled. In unburned settings or those with an abundance of logs the samples were taken in order as they were encountered in cardinal directions. This procedure was followed to minimize personal bias.

A one square-foot area of bark was removed from the up-hill side of each log. The sample was centered on the longitudinal axis of the log or chunk.

The information recorded from each square-foot sampling area included the number of entrance holes for each genus of ambrosia beetle, the bark thickness, diameter, orientation and position of the log. Bark thickness was recorded to the nearest one-fourth inch. Diameter was recorded by two-inch classes. Orientation was either north-south or east-west. Log position was either in contact with the ground at the point of sample or above the ground.

As mentioned previously, the genera of beetles present were separated by the size of the entrance tunnel. A dissecting needle cut to fit snuggly into a Platypus gallery fits loosely into a gallery made by Trypodendron and will not fit without forcing into a gallery constructed by Gnathotrichus. Of the tree species sampled in this study, only western hemlock and grand fir are likely to be attacked by all three genera. The slivery boring dust of Platypus is a better indicator than using the modified dissecting needle because the needle can be forced into the galleries of Gnathotrichus if the wood is especially green or rotten. The boring dust of Gnathotrichus can be distinguished from that of Trypodendron when viewed with a good hand lens. The boring dust of the former is in the form of small "C-shaped" shavings while that of the latter is composed of flat, irregularly shaped particles. In logs that have been down for several years the boring dust of Platypus appears more like that of Trypodendron.

Complicating Factors

Many factors confound this experiment. To begin with, the exact dates the settings were felled were hard to obtain as the Forest Service does not keep such information in their files. Also the elapsed time between the beginning of felling and completion was not known. It may have been that the period of cutting extended over a full flight period of the beetles. The settings were located on several different aspects and varied greatly in elevation. Many of the settings contained beetle-killed trees from the 1950-53 epidemic of the Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopk.). Logs from these trees as well as some from recent windfalls were often difficult or impossible to separate from those that were alive at the time of felling. The species distribution was heavily weighted in favor of Douglas-fir. Observations on grand fir and hemlock were quite limited. The exact dates of slash burning were not determined. It is entirely possible that some settings were burned during the spring flight of the beetles. What affect this would have on attack intensity is not known. There was also variation in each setting in that many logs were situated in damp stream beds while others were exposed to the direct rays of the sun on dry scorched slopes. The logs sampled along the shaded margins of the settings may have been differently attacked than those in the center. The type of material sampled could also have had some influence on attack. Only small, broken parts of logs and cull logs were available for study. If whole, sound logs had been sampled the results may have been different. Observations from a few felled, sound logs indicate that they are more heavily attacked than the culls and chunks.

To partially compensate for this great variation, as many samples as time would permit were taken. Three hundred and seventeen logs were sampled, of which 242 were Douglas-fir, 45 grand fir and 30 western hemlock.

In this experiment existing conditions were evaluated to determine answers to the previously mentioned questions. If time had permitted a better procedure would have been to periodically fell a few trees of each species for several years. Using this approach one could systematically follow the pattern of attack for the exact felling dates could be controlled to fit the needs of the study. Much of the variation that was found could be reduced by equalizing the period of time between fellings, felling groups of trees that are similar in size, age and bark thickness and by felling the trees in areas with the same elevation and aspect. In such a regulated experiment the role of other variables and interaction of variables might be determined and consequently, more confidence could be placed in the findings. Under the circumstances, such an experiment was not possible. It is hoped, however, that this short-termed study has provided useful information on the habits of ambrosia beetles. The results seem to indicate that a more comprehensive study seems justified.

Analysis of Data

The majority of these data were analyzed by the statistical department at Oregon State College. Due to the many variables and the unequal number of observations recorded for each of these variables, the computing procedure was necessarily complicated. There were five variables for each species of tree and beetle with observations ranging from 7 to 199. Analysis of variance by the least squares method was used. The mean squares (MS) for length of exposure, log size, bark thickness, position and orientation were divided by the error MS. This resulted in what is termed the F value. The hypotheses being tested are that the intensities of attack remain the same regardless of the level of the variable. Using exposure as an example, the hypothesis is that the attack intensity remains the same regardless of the length of time the logs were exposed to attack. If the F value computed for this variable is greater than the value in the F tables with corresponding degrees of freedom, the hypothesis is rejected, or the intensity of attack does vary with length of exposure.

In the analysis of the exposure variable, the sample logs were categorized by the number of summers they had been on the ground. The oldest settings examined were felled in February, 1953, therefore, the categories would be less than one summer, one summer, two summers and three summers. Douglas-fir logs were classified as large (41 inches and over), medium (21-40 inches) and small (less than 21 inches). Log size was calculated from a random sample of 50 logs. The mean log diameter plus and minus one standard deviation was classified as medium. Large logs were those larger than the mean plus one standard deviation and small logs were those smaller than the mean minus one standard deviation. Bark thickness was computed in the same way. This resulted in medium bark being ½ to 1 3/4 inches thick, thick bark 1 3/4 inches and over and thin bark less than ½ inch. It was intended that grand fir and western hemlock logs be handled in this same manner, but because of the small sample size and great variation, log size was reduced to large (21 inches and over) and small (less than 21 inches). Bark thickness was classified as thick (over ¼ inch) and thin (¼ inch and less).

When the computed F value is greater than the corresponding F value from the Table of F, it implies that attack intensity varies with log diameter, bark thickness or other variable. However, in variables composed of more than two categories, the F value does not show the relationship among the individual mean number of attacks. For example, if the F value for the bark thickness variable is large, it implies that the mean number of attacks in thin, medium and thick-barked logs are not the same, but it does not provide enough information to show if the mean number of attacks for each degree of bark thickness are different. It may well be that the number of attacks in thin and medium-barked logs are the same, but that the number of attacks in thick-barked logs is significantly different from each of the former. To show these differences tests with individual degrees of freedom would have had to be used. This would have required much more time and money as the data do not readily lend themselves to this type of analysis because of the unequal number of observations and the great variation. The coefficients of variation, which range from 90 to 243 per cent indicate this quite clearly.

In addition, the square of the multiple correlation coefficients vary from .221 to .559. These coefficients show that in one case 22 per cent of the variation is accounted for while in the other 56 per cent is accounted for. In other words, 44 and 78 per cent of the variation has not been explained. It may be due to elevation, climate or other factors.

Some information is available from the means of the variables in which the F values were greater than the table values. For example in Douglas-fir attacked by Gnathotrichus, the mean attack intensities per square foot of log surface for thin, medium and thick bark are 2.71, 2.84 and 6.14. The F value showed that attack intensity varies with bark thickness. From the means indicated above it appears that there is a direct relationship between the number of attacks per square foot and bark thickness. There apparently is a significant difference between the number of attacks in thick-barked logs and those with medium bark and thinner, but the difference between the attacks on thin and medium-barked logs is not significant.[6]

[6]These predictions were made with advice from Dr. R. G. Peterson of the statistical department, Oregon State College.

Although the conclusions from this study must be made with reservations, the results do provide some important information, other than purely observational, on the occurrence of ambrosia beetles in coniferous logs in this area.

Results of Study and Additional Observations

Even though significant results were obtained for several variables, the square of the multiple correlation coefficients show that from 44 to 78 per cent of the variation is unexplained by the data collected. Therefore, even with highly significant results one cannot be absolutely certain that a variable such as exposure, bark thickness or other is entirely the cause. When the square of the correlation coefficient is greater than .5, the significant results are more likely to be due to the sampled variables than the unsampled ones.

Percentage of logs infested: Ninety-one per cent of 307 sample logs that had been exposed to ambrosia beetles for at least part of a summer were attacked by *Gnathotrichus*, *Trypodendron* or *Platypus*. If these data are tabulated so that logs with at least one ambrosia beetle attack are assigned a value of "1" and those unattacked "0", this becomes a sample from a binomial population. In other words attacked logs are considered successes and unattacked logs failures. Considering all logs together, regardless of species, the confidence interval calculated from the sample mean and variance is .8776 to .9401 with a confidence coefficient of .95. This indicates that if all possible samples were taken and similar confidence intervals calculated, 95 per cent of them would include the true or population mean of the number of logs attacked. This sample shows that if coniferous logs are left exposed to ambrosia beetles in Benton County, from 88 to 94 per cent may be attacked.

When the sample logs are considered separately by species, the percentage of logs attacked for Douglas-fir, grand fir and hemlock is 93, 89 and 91 per cent respectively. The confidence intervals for the separate species are tabulated in Table 1.

Relative intensities of attack: Confidence intervals for the relative intensities of attack for each genus are shown in Table 5. In computing these confidence intervals, all sample logs were used regardless of the length of time they were exposed to attack. As many of the logs had yet to be attacked by the beetles, these intervals are somewhat low. The interval for Platypus includes all Douglas-fir samples and as it was found in only one of 242 logs, the resulting interval is drastically reduced.

Trypodendron attacks in the greatest numbers. The number of attacks per square foot of log surface for this genus can be predicted with a confidence coefficient of .95 to be somewhere between 5.24 and 6.80. Gnathotrichus will attack at about half this rate. The confidence interval is 2.69 to 3.63 attacks per square foot. If all logs are taken into consideration Platypus attacks at the rate of .26 to .74 attacks per square foot, but in grand fir the number of attacks is considerably greater. The mean number of attacks for all grand fir logs, including those that had not been exposed for a full summer was 3.22 per square foot. The highest intensities of attack per square foot for Gnathotrichus, Trypodendron and Platypus were 25, 36 and 21 respectively.

The order of attack intensity is just the opposite of the observed depth of penetration by each genus. Trypodendron, which attacks in the greatest numbers, seems to penetrate the wood least. Gnathotrichus, which attacks in the next greatest numbers, penetrates to a greater depth than Trypodendron, although both genera seem to be generally confined to the sapwood in Douglas-fir. Platypus penetrates very deep into grand fir and hemlock and in the two observations in Douglas-fir it also penetrated far deeper than the other two genera. Xyleborus was not found in any coniferous logs. The work was observed in Pacific madrone (Arbutus menziesii Pursh.).

Species preference: Dr. Peterson of the Oregon State College Statistical Service recommended that the data from Douglas-fir, grand fir and hemlock not be combined to determine if a certain tree species was most susceptible to ambrosia beetles. The reason for this was because of the great difference of the error mean squares for each of the tree species. Had the variance or error mean squares been somewhat the same, all the data could have been combined and such an analysis computed. The mean number of attacks per square foot for all ambrosia beetles is 10.4 in Douglas-fir, 6.2 in grand fir and 6.6 in western hemlock.

Trypodendron and Platypus showed a preference in the species of log they attacked. Platypus wilsoni occurred much more abundantly in grand fir than in hemlock. It was only encountered once in a sample log of Douglas-fir. The mean intensities of attack for grand fir and hemlock are 3.22 and .40 entry holes per square foot of log surface respectively. Just why this beetle should almost completely ignore Douglas-fir is not known. One can postulate several reasons among which are: (1) that a distasteful substance may be present in Douglas-fir bark or wood; (2) that the moisture condition or other condition is not satisfactory for the growth of the fungus upon which *Platypus* subsists; (3) that the wood is too hard to allow for the deep galleries usually constructed by this species.

Trypodendron showed a distinct preference for Douglas-fir, but it is believed that this is because most of the settings which contained grand fir and hemlock were felled in the spring of the year which, as shown in Table 6, appears to be the period of least attack. Several observations of 20-30 attacks were recorded in both grand fir and hemlock. Plate No. 5 shows a grand fir log moderately attacked by *Trypodendron lineatum*. This species was also the only ambrosia beetle observed in western red-cedar sample logs. Although it apparently did not attack this species with the same intensity, as many as 16 attacks per square foot of log surface were noted on large stumps.

Gnathotrichus showed no special preference for any of the coniferous logs sampled. Several galleries believed to be constructed by this genus were observed in a large western red-cedar stump. In Washington, *Gnathotrichus sulcatus* was observed in considerable numbers in western red-cedar. Members of this genus were also found in golden chinquapin and red alder.

Diameter and bark thickness: In Douglas-fir the intensities of attack by *Gnathotrichus* and *Trypodendron* were found to vary with log diameter and bark thickness (Table No. 2).

The F value for log diameter in *Gnathotrichus* is greater than the tabular value at the five per cent level, but not at one per cent. Attacks per square foot by *Gnathotrichus* seem to increase as log diameter and bark thickness increase. The mean attacks for small (10-20"), medium (21-40") and large (41" plus) logs are 2.11, 3.57 and 4.32 respectively. This almost appears to be a linear relation. The mean number of attacks per square foot for the various bark thicknesses are 2.71, 2.84 and 6.14 for thin (less than ½"), medium (1½ to 1 5/8") and thick (1 3/4" and over) bark. The thick bark value is probably significantly different from either the thin or medium value. These data indicate that *Gnathotrichus*, which inhabits logs all year around and for several years, prefers large logs with thick bark probably because of the higher moisture content which favors the growth of ambrosia fungi.

Trypodendron, on the other hand, spends only about six months in the log and seems not to be so particular about the size or bark thickness. Both the log diameter and bark thickness F values were larger than the values from the F tables at the one per cent level. The means for small, medium and large logs are 7.59, 7.72 and 4.32. This would indicate that small and medium logs are equally attacked while large logs are attacked somewhat less. Very thin and thick-barked trees seem to be less attractive to Trypodendron than medium-barked trees. The mean attacks per square foot for thin, medium and thick-barked trees are 2.14, 7.40 and 3.20. These means are highly influenced by ones concept of bark thickness. For instance, if the mean number of attacks in thin-barked trees was computed from data including trees with ½ inch bark the mean would be 8.22 instead of 2.14. Additional personal observations in this area confirm the fact that the thick-barked logs are less heavily attacked. These logs may be attacked less heavily for the opposite reason Gnathotrichus attacks them. Trypodendron is reported to prefer partially seasoned wood (52, p. 37).

The thicker-barked trees are more resistant to drying out and are probably too moist or green for the beetles.

Because of the fewer observations in grand fir and hemlock, log size was reduced to two categories--large (21" and over) and small (less than 21"). Bark thickness was similarly reduced to thin (¼" and less) and thick (¼" and over). None of the F values were large enough to show that these variables had an effect on attack intensity. The F values for _Platypus_ were quite close to the tabular values at the five per cent level, however, and the means may give some idea of the difference. The mean number of attacks per square foot for small diameter logs was 2.06 while for large logs it was 6.42. For thin bark the mean was .33; for thick bark 4.27. Field observations in addition to those data indicate that _Platypus_ prefers the larger, thicker-barked trees. In down, whole trees, the highest intensities of attack are in the butt and second logs. The top logs are least heavily attacked.

Length of exposure: The exposure F values for both _Gnathotrichus_ and _Trypodendron_ in Douglas-fir are significant. This indicates that attack intensity may vary with time. The mean number of attacks per square foot of log surface for logs exposed to <u>Gnathotrichus</u>, for less than one summer, one summer, two summers and three summers are 1.28, 3.54, 5.64 and 4.10 respectively. These means signify that <u>Gnathotrichus</u> may continue to attack logs for several years. No data were recorded for logs exposed for four or more summers, but observations have indicated that only logs in very moist, shaded places are likely to contain live <u>Gnathotrichus</u> after such a period of time.

The exposure F value for <u>Trypodendron</u> was significant at the five per cent level, but the means show an impossible trend. The mean number of attacks per square foot for logs exposed for less than one summer, one summer, two summers and three summers are 7.33, 9.22, 5.76 and 3.80. These means indicate that the total number of attacks decrease with the length of time the logs were exposed to attack. This is, of course, not possible. If a log contains a total of nine attacks per square foot one year it is not going to contain only five attacks after being exposed still longer. The square of the multiple correlation coefficient for <u>Trypodendron</u> in Douglas-fir is .5428. This indicates that the data gathered account for 54 per cent of the variation while 46 per cent remains unaccounted for. The impossible trend shown above is probably due to some environmental resistance such as weather, parasites, predators or food supply which regulates the number of insects available for attack each year.

Since the square of the multiple correlation coefficient in *Gnathotrichus* is .5519, one could logically ask if the increase in number of attacks was also due to unexplained variation. This is entirely possible, but it is less likely because the means show opposite trends in *Gnathotrichus* and *Trypodendron*. Since the trend in *Trypodendron* is impossible from the exposure standpoint above, the trend for *Gnathotrichus* is strengthened because environmental resistance, or whatever the causative factor, is quite likely to work against this genus also.

Platypus wilsoni was not present in enough sample logs to calculate an attack intensity trend with exposure. It is believed, however, that this species will attack the larger logs more than once. During the course of the field work for this paper, this species was found in Douglas-fir in only two instances. In a standing beetle-killed tree that is known to have been dead for over four years, this species was quite numerous. A number of live specimens were taken from large grand fir stumps that had been dead long enough for the sapwood to become quite decayed.

In neither the grand fir or hemlock analyses were the exposure F values significant.

Orientation and position: As each sample log was examined, the position of the log (whether in contact with the ground at the point of sample or above the ground) and the orientation (whether north-south or east-west) were recorded. Each of these variables were analyzed to determine if the number of attacks were the same irregardless of position or orientation.

In none of the tree species were the position F values significant. This indicates that the number of attacks were the same in logs resting on the ground and those not in contact with the ground. The reason for testing position is because it was speculated that logs above the ground would dry out sooner than those on the ground and, consequently, be less attractive to ambrosia-beetle attack. Apparently this is not the case.

Orientation F values were highly significant (one per cent) for *Trypodendron* in Douglas-fir and *Platypus* in grand fir. The F value for *Trypodendron* in grand fir was significant at the five per cent level.

In both Douglas-fir and grand fir, *Trypodendron* seemed to prefer logs oriented east and west. As data were not collected from the north and south sides of the logs oriented east and west, one cannot be sure whether or not solar radiation is responsible for this difference. To confuse the issue further, _Platypus wilsoni_ seems to prefer those logs oriented north and south.

Keen (43, p. 271) and Chamberlin (10, p. 97) indicate that logs oriented north and south have higher subcortical temperatures and, consequently, would dry out faster. If this is the case the above orientation preferences make still less sense as _Platypus_ which inhabits a log for a longer period of time should attack east-west logs with greater intensity. More information is needed before any definite conclusions may be reached concerning orientation.

Additional information: All Douglas-fir logs that had been on the ground for at least one summer were grouped according to the season of year in which they were felled. Analysis of variance computations were carried out. The hypothesis being tested was that the attack intensitity was the same irregardless of the season the logs were felled. With _Gnathotrichus_ the F value was not great enough to reject this hypothesis, but with _Trypodendron_ it was highly significant. The mean intensities of attack for fall, winter, spring and summer are 8.9, 11.0, 3.3 and 7.1. Those logs felled in the spring seem to be the least susceptible to attack while those felled in the winter are the most susceptible.

The results of this analysis are in agreement with an experiment carried on in Canada (52, p. 38).

Summary by Genus of Ambrosia Beetle

Trypodendron: Trypodendron attacks were most heavily concentrated in 21-40 inch Douglas-fir logs with bark ½ to 1 3/4 inches thick. An average of more than seven attacks per square foot occurred in Douglas-fir logs. The number of attacks in grand fir and hemlock were considerably less, but it is believed that at least part of this difference is due to the time of year the sample fir and hemlock logs were felled. Trypodendron does not seem to attack a log more than once and it prefers logs that are felled during the winter. Logs felled during the spring are attacked the least.

The members of this genus definitely do not appear to attack with the intensities that are reported in Canada where attacks of one to two hundred per square foot are not uncommon (52, p. 39). In July, 1956, the author observed as many as 87 attacks per square foot in Douglas-fir logs near Mt. St. Helens in Washington. Counts from several infested logs indicate that the average intensity of attack is around 25 per square foot. In this area *Trypodendron* were observed quite numerously in limbs as small as two inches in diameter. In Benton County the smallest material observed infested with this genus was six inches. It seems that this genus attacks with greater intensities as it progresses northward.

Specimens of *Trypodendron* were observed in flight as early as the first week in April. By the end of April, previously uninfested logs had an average of seven attacks per square foot. Gallery construction was quite rapid and by the end of the month the beetles were one-half inch or more into the sapwood where the first branch was constructed. Galleries of more than three inches in depth are not common in Douglas-fir. In all cases it was the female observed excavating the gallery while the male stood guard at the entrance. Copulation was observed to take place at the juncture of two galleries as well as on the surface of the logs. Egg laying began early in May and by the end of the month the young larvae had begun constructing larval cradles. Although not in this same area, new adults or *Trypodendron lineatum* were collected emerging from their galleries in the middle of July.

All specimens collected during the field work of this thesis were *T. lineatum*. No known specimens of *T. rufitarsis* were collected, but one specimen believed to be this species was taken hibernating in the moss on a maple tree in February, 1956.

Trypodendron lineatum was the only species incurred in western red-cedar. Several moderate attacks were noted, especially on the larger stumps.

Gnathotrichus: In Douglas-fir, *Gnathotrichus* shows a preference for large, thick-barked logs. This genus attacks hemlock and grand fir with about the same intensity. The confidence interval of attacks per square foot for all tree species is 2.69 to 3.63 which is about half that for *Trypodendron*.

The data indicate that this genus may attack the same log several times, but few live beetles were found in trees dead longer than four years. Apparently the time of year the logs are cut has no bearing on attack intensity.

Specimens of this genus were caught in flight at the end of May, but several were noted on the outside of the logs before this time. As early as April, fresh boring dust was noted on the bark of several infested logs.

Gnathotrichus retusus and *G. sulcatus* were collected in about equal numbers. Both species were taken and identified from Douglas-fir, hemlock and grand fir. *G. sulcatus* may show a slight preference for Douglas-fir.

The depth of the galleries excavated by these species varies greatly. In grand fir, galleries up to eight inches deep were measured. In Douglas-fir they penetrate much less radially. In some logs of all species, the tunnels branch almost immediately at the juncture of the cambium and the wood and then follow the annual rings for as much as eight inches. In other logs the insects bore directly into the log for several inches before constructing side galleries. *Gnathotrichus* seems to construct many more larval cradles than either of the other genera.

Platypus: *Platypus wilsoni* shows a definite preference for grand fir logs, and although the F values for size and bark thickness in the analysis of variance are not significant, it is believed that this species prefers the larger, thick-barked logs. It occurs less frequently in hemlock and seldom in Douglas-fir.

Those beetles have a tremendous excavating capacity. Logs that had been attacked for only two months in the fall of the year were penetrated to a depth of eight inches. Several large stumps over four feet in diameter were penetrated to within a few inches of the center.

Both male and female were observed to overwinter at the entrance of the gallery with the male nearer the outside. When disturbed, both sexes emit an audible, squeeking sound and retreat into the gallery for protection. Very few specimens were collected that had a full complement of tarsal segments. This loss apparently does not hamper their travel within the galleries. The members of this genus are the most awkward of ambrosia beetles when walking around outside the galleries.

Both *Platypus wilsoni* and *Gnathotrichus sulcatus* were observed quite numerously in live hemlock trees that had been injured by logging or fire. The beetles would bore their galleries in or near the logging scar. On the burned trees they occurred mostly near the base.

Conclusions:

Coniferous logs in Benton County seem to be less severely attacked than those in Canada, but it does not take many "pinholes" to reduce lumber grade significantly.

Ninety-one per cent of all logs sampled contained one or more ambrosia beetle attacks per square foot of log surface. In Douglas-fir the mean intensity of attack was 10.4 holes per square foot. In grand fir and hemlock the averages were 6.2 and 6.6. Most of the logs sampled were fully exposed to the drying effects of the sun and wind. Shaded and partially shaded logs may show heavier attacks, but whether they do or not the author is of the opinion that the data presented in this paper are sufficient evidence to investigate the amount of damage caused by ambrosia beetles and to search for means of reducing this damage in Benton County, Oregon. The time has yet to come when all logs will be immediately removed from the woods. Studies should be undertaken to decide if the cost of spraying logs or moving them faster will pay dividends.

TABLES

TABLE 1

CONFIDENCE INTERVALS FOR PERCENT OF LOGS ATTACKED AFTER BEING EXPOSED TO AMBROSIA BEETLES FOR AT LEAST PART OF ONE SUMMER[1]

	Douglas-fir	Grand fir	Hemlock	Total
No. of Successes:	211	37	31	279
No. of Failures:	21	3	4	28
Total or n:	232	40	35	307
Mean or $\bar{y}$	.9095	.9250	.8851	.9088

Confidence Intervals of Population Means at Five Percent Level

All logs:	.8766	to	.9410	or	88 to 94%
Douglas-fir:	.8726	to	.9464	or	87 to 95%
Grand fir:	.8434	to	1.0000	or	84 to 100%
Hemlock:	.7803	to	.9911	or	78 to 99%

[1]Considered a binomial population with attacked logs as successes and unattacked logs as failures.

TABLE 2

ANALYSIS OF VARIANCE (Douglas-fir)

Source Variation	DF	GNATHOTRICHUS SS	GNATHOTRICHUS MS	GNATHOTRICHUS F	TRYPODENDRON SS	TRYPODENDRON MS	TRYPODENDRON F
General Mean	1	457.22	457.22		157.38	157.38	
Exposure	3	747.17	249.06	18.2**	623.98	207.99	3.9*
Log Diameter	2	95.81	47.90	3.5*	753.50	376.75	7.0**
Bark Thickness	2	312.37	156.18	11.5**	592.98	296.49	5.5**
Orientation	1	24.31	24.31	1.8	448.39	448.39	8.4**
Position	1	42.12	42.12	3.1	4.66	4.66	.9
Error	232	3168.56	13.66		12439.08	53.62	
Total	242	7071.00			27205.00		
Multiple Correlation Coefficient Squared (R^2)			.5519			.5428	
General Mean ($\bar{y}$)			3.330			7.250	
Coefficient of Variation (c.v.)			90.1%			101.0%	

* Indicates significance at the 5% level.
** Indicates significance at the 1% level.

TABLE 2 (CONTINUED)

MEANS

Grand Mean:				
Gnathotrichus:	3.33			
Trypodendron:	7.25			
Log Diameter:	20" & less	21-40"	Over 40"	
Gnathotrichus:	2.11	3.57	4.32	
Trypodendron:	7.59	7.72	4.30	
Bark Thickness:	Less than ½"	½-1 5/8"	Over 1 5/8"	
Gnathotrichus:	2.71	2.84	6.14	
Trypodendron:	2.14	7.40	3.20	
Log Orientation:	North-South	East-West		
Gnathotrichus:	3.65	2.86		
Trypodendron:	6.07	8.71		
Log Position:	On Ground	Above Ground		
Gnathotrichus:	3.20	3.60		
Trypodendron:	7.85	5.90		
Length of Exposure:	Less than 1 yr.	1yr.	2yr.	3yr.
Gnathotrichus:	1.28	3.53	5.64	4.10
Trypodendron:	7.33	9.22	5.76	3.80

TABLE 3

ANALYSIS OF VARIANCE (Grand fir)

Source of Variation	DF	GNATHOTRICHUS			TRYPODENDRON			PLATYPUS		
		SS	MS	F	SS	MS	F	SS	MS	F
General Mean:	1	25.14	25.14		20.76	20.76		106.80	106.80	
Log Diameter:	1	3.93	3.93	.20	.05	.05	.01	85.54	85.54	3.67
Bark Thickness:	1	.01	.01	---	.14	.14	.02	70.49	70.49	3.03
Orientation:	1	30.91	30.91	1.62	34.30	34.30	4.16*	245.10	245.10	10.50**
Position	1	.21	.21	.01	2.88	2.88	.35	.85	.85	.04
Error:	40	766.78	19.17		341.13	8.26		934.46	23.36	
Total:	45	1105.00			438.00			1873.00		
	R^2		.3060			.2212			.5011	
	$\bar{y}$		2.47			1.16			3.22	
	c.v.		177.2%			247.8%			150.1%	

TABLE 3 (CONTINUED)

MEANS

Grand Mean:		
Gnathotrichus:		
Trypodendron:		
Platypus:		
Log Diameter:	20" & less	Over 20"
Gnathotrichus:	2.18	3.25
Trypodendron:	1.11	1.00
Platypus:	2.06	6.42
Bark Thickness:	½" & less	Over ½ "
Gnathotrichus:	2.25	2.54
Trypodendron:	1.17	1.15
Platypus:	.33	4.27
Log Orientation:	North-South	East- West
Gnathotrichus:	3.56	1.86
Trypodendron:	0.00	1.79
Platypus:	6.19	1.59
Log Position:	On Ground	Above Ground
Gnathotrichus:	2.58	2.17
Trypodendron:	1.03	1.50
Platypus:	3.73	1.83

TABLE 4

ANALYSIS OF VARIANCE (Western hemlock)[1]

		GNATHOTRICHUS			TRYPODENDRON		
Source Variation	DF	SS	MS	F	SS	MS	F
General Mean	1	45.87	45.87		8.38	8.38	
Log Diameter	1	2.71	2.71	.24	5.13	5.13	.24
Bark Thickness	1	10.80	10.80	1.19	26.14	26.14	1.19
Orientation	1	5.84	5.84	.65	.99	.99	.05
Position	1	1.23	1.23	.14	3.77	3.77	.17
Error	23	207.82	9.04		505.92	22.00	
Total	28	494.00			852.00		
	R^2		.5793			.4062	
	$\bar{y}$		2.86			3.28	
	c.v.		105.1%			109.6%	

[1]Although *Platypus* occurs quite plentifully in some hemlock logs, it was not present in enough sample logs to be included in this analysis.

TABLE 4 (CONTINUED)

MEANS

Grand Mean:		
Gnathotrichus:	2.86	
Trypodendron:	3.28	
Log Diameter:	20" & less	Over 20"
Gnathotrichus:	2.00	3.70
Trypodendron:	3.14	3.42
Bark Thickness:	½" & less	Over ½"
Gnathotrichus:	1.46	4.06
Trypodendron:	4.30	2.40
Log Orientation:	North-South	East-West
Gnathotrichus:	1.92	3.55
Trypodendron:	4.08	2.68
Log Position:	On Ground	Above Ground
Gnathotrichus:	3.28	1.57
Trypodendron:	3.42	2.85

TABLE 5

ANALYSIS OF VARIANCE (All Species)

Source of Variation	DF	GNATHOTRICHUS SS	GNATHOTRICHUS MS	GNATHOTRICHUS F	TRYPODENDRON SS	TRYPODENDRON MS	TRYPODENDRON F	PLATYPUS SS	PLATYPUS MS	PLATYPUS F
Between Species	2	30.36	15.18	.85	1648.72	824.36	16.8**	394.27	197.13	49.5**
Within Species	314	5585.11	17.79		15,408.20	49.07		1452.98	4.62	

MEANS

Species	N	GNATHOTRICHUS Total Attacks	GNATHOTRICHUS Mean	TRYPODENDRON Total Attacks	TRYPODENDRON Mean	PLATYPUS Total Attacks	PLATYPUS Mean	ALL Total Attacks	ALL Mean
Douglas-fir	242	805	3.33	1755	7.25	1	0.00	2560	10.6
Grand fir	45	111	2.47	52	1.21	145	3.22	308	6.8
Hemlock	30	87	2.90	100	3.33	12	.40	199	6.6
Totals	317	1003	3.16	1907	6.02	157	.50	3067	9.7

CONFIDENCE LIMITS OF MEANS

	GNATHOTRICHUS	TRYPODENDRON	PLATYPUS
Upper limit	3.63	6.80	.74
Lower limit	2.69	5.24	.26

TABLE 6

ANALYSIS OF VARIANCE TO DETERMINE IF THE FELLING TIME INFLUENCES ATTACK INTENSITY IN DOUGLAS-FIR

GNATHOTRICHUS:

Source of Variation	Degrees Freedom	Sum of Squares	Mean Square	F
Between seasons	3	60.84	20.28	.95
Within seasons	158	3365.16	21.30	
Total	161	3426.00		

TRYPODENDRON:

Source of Variation	Degrees Freedom	Sum of Squares	Mean Square	F
Between seasons	3	1387.08	462.36	9.88**
Within seasons	198	9271.30	46.82	
Total	201	10,658.38		

SEASONAL MEANS

	Fall	Winter	Spring	Summer
GNATHOTRICHUS:	3.4	4.0	4.6	4.9
TRYPODENDRON:	8.9	11.0	3.3	7.1

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