AN ABSTRACT OF THE THESIS OF

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Title HOST SELECTION AND WOOD CHANNELIZATION BY BEETLES IN CONIFER LOGS IN WESTERN OREGON

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Abstract approved: ______________________________
Timothy D. Schowalter

The host preferences and wood channelization rates of scolytid and cerambycid beetles were studied at the H. J. Andrews Experimental Forest (Lane County, Oregon) during 1986 and 1987. Attack density and gallery volumes were measured in fall-felled experimental logs of four major conifer species: Douglas-fir (*Pseudotsuga mensiesii* (Mirb.) Franco), western hemlock (*Tsuga heterophylla* (Raf.)Sarg.), Pacific silver fir (*Abies amabalis* (Dougl.)Forbes), and western redcedar (*Thuja plicata* Donn).

The ambrosia beetles (Coleoptera: Scolytidae), *Trypodendron lineatum* (Olivier) and *Gnathotrichus* spp., were significantly more abundant in Douglas-fir and western hemlock than in silver fir or western redcedar, but *Xyleborinus saxeseni* (Ratzeburg) showed no discrimination among the four tree species. The average emergence of ambrosia beetle brood per gallery was 1.8 in spring-felled

Douglas-fir logs and 2.2 in western hemlock. The data indicate a declining ambrosia beetle population emerging from these logs.

About 0.16% of the sapwood volume of Douglas-fir and about 0.18% of the sapwood volume of western hemlock were removed by *Trypodendron*. About 0.01% of the sapwood volume of Douglas-fir and about 0.06% of the sapwood volume of western hemlock were removed by *Gnathotrichus*.

The bark beetles (Coleoptera: Scolytidae) *Dendroctonus pseudotsugae* Hopkins and *Dryocoetes autographus* Ratzeburg excavated about 7.6% of Douglas-fir phloem surface area. *Pseudohylesinus sericeus* (Mannerheim) removed 6.8% of Pacific silver fir phloem surface area. Long-horned beetles (Coleoptera: Cerambycidae) excavated an additional 2.3% of Pacific silver fir phloem surface area.

These data indicate that each tree species has a distinct boring insect species pool with differences in channelization rates through time. Colonization and fragmentation of fallen trees by beetles are important to the initiation of the decomposition process in forest ecosystems.

Host Selection and Wood Channelization by Beetles
in Conifer Logs in Western Oregon

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Introduction

Beetles belonging to the families Scolytidae and Cerambycidae pioneer the log decomposition process in forest ecosystems (Francke-Grosmann 1964, Furniss and Carolin 1977, Coulson and Witter 1984, Maser and Trappe 1984). As the beetles chew through the bark, they permit entry by other organisms less capable of penetrating the bark barrier. The beetles themselves introduce fungal spores, bacteria, protozoa, nematodes, and mites and initiate cycling of nutrients from logs (Swift 1977, Maser and Trappe 1984).

However, host selection and the rate of wood channelization are influenced by tree species, chemical composition, temperature and moisture. Different wood boring beetle species typically require different host materials for reproduction and development (Rudinsky 1962, S. L. Wood 1982), although some beetle species may attack logs of several tree species (Chapman 1961, Bletchly and White 1962, Chapman et al. 1963, Dyer and Chapman 1965). Unfortunately, little information is available on host preference and selection behavior of these beetles when there are several host species available in the field. Less information is available on the rate of wood channelization by beetles.

As part of a long-term study of log decomposition, I investigated host selection and wood channelization by bark- and wood-boring beetles. Beetle behavior was compared among four conifer species at the H. J. Andrews Experimental Forest in western Oregon.

Literature Review

Most species of the beetle families Scolytidae and Cerambycidae complete their entire life cycles in wood, except for a short dispersal period (Rudinsky 1962, Furniss and Carolin 1977, Knight and Heikkenen 1980, Coulson and Witter 1984). The scolytid ambrosia beetles are widespread wood-boring species found throughout the northern boreal region in Asia, Europe and North America (Annila et al. 1972, Hosking 1972). Ambrosia beetles attack logs of many coniferous tree species, usually during the spring, and select primarily logs felled the preceding autumn or winter (Dyer and Chapman 1965, Annila et al. 1972, Hosking 1972, Shore et al. 1987).

Two major genera in the northwestern United States are Trypodendron and Gnathotrichus (Coleoptera: Scolytidae). Overwintering Trypodendron lineatum (Olivier) are found in the forest litter or duff in the vicinity of brood logs (Kinghorn and Chapman 1959). High mortality may occur during years when unseasonably low temperatures occur in the absence of protective snow cover (Kinghorn and Chapman 1959, Chapman 1960, Dyer and Kingorn 1961). Newly emerged brood adults rarely mate (Fockler and Borden 1972). Mating activity of revived overwintering beetles increases during the winter, providing evidence that overwintering populations undergo a reproductive diapause or hibernation (Fockler and Borden 1972). These beetles leave their hibernating quarters early in the spring (April-June) and seek new hosts (Daterman 1964, Pulliainen 1965).

Many investigators (e.g. Bletchley 1961, Chapman 1963, D. L. Wood 1982) have shown that host selection by T. lineatum is strongly influenced by attractive odors from logs. Pulliainen (1965) found that light and moisture also act as cues for the beetles: under moist conditions the beetles orient away from light; under dry conditions the beetles orient toward light.

Because T. lineatum cultivates and feeds on ambrosia fungi (Rudinsky 1962, Franke-Grossmann 1964), the moisture content of logs is very important for beetle survival. Four hours of desiccation and starvation are sufficient to kill 50% of the beetles (Pulliainen 1965).

This species has only one generation a year but may produce two or more broods. The period of emergence extends from early July to late September (Annila et al. 1972) with peak emergence differing from location to location and year to year. At Froslev, Denmark, the second peak of emergence occurred in mid-September while at Rovaniemi in northern Finland, emergence peaked in late September and early October (Annila et al, 1972). In coastal British Columbia, the peak of emergence was in mid-July (Borden and Fockler 1973). Borden and Forkler (1973) concluded that a critical ambient temperature of 24° C (75° F) induces mass emergence. The mean number of emerging Trypodendron per female parent has been measured at 4-10 in successful galleries (Dyer 1963, Borden and Fockler 1973, Shore et al. 1987).

Less information is available on host preference, sapwood excavation and emergence of Gnathotrichus retusus (LeConte) and Gnathotrichus sulcatus (LeConte) (Coleoptera: Scolytidae). These two species often have been treated as one (Chapman and Kinghorn 1958). Prebble and Graham (1957) reported that Gnathotrichus spp. commonly disperses to new hosts one or two weeks later than Trypodendron. Flight activity was related to temperature during the spring flight period (Daterman 1964).

Xyleborinus saxeseni (Ratzeburg) (Coleoptera: Scolytidae) attacks a wide range of tree species but is very selective in the condition of materal it attacks (Hosking 1972). It occurs throughout Europe, North Africa, Asia Minor, the Caucausus, and North America (Hosking 1972)). In contrast to other scolytids which are known to respond to aggregation pheromones, X. saxeseni has not shown mass attack behavior (Hosking 1972).

The host preference and selection behavior of ambrosia beetles when different hosts are available remains is poorly known. The amount of wood processed by ambrosia beetles has not been reported.

The scolytid bark beetles and cerambycid beetles are relatively more host specific than ambrosia beetles (Furniss and Carolin 1977, Stark 1982, S. L. Wood 1982). There is considerable controversy surrounding the ability of these beetles to locate and select suitable hosts. On one side, some investigators reported that the natural resistance of trees to bark beetles was reduced by moisture or carbohydrate stress (Hall 1958, Vite 1961, Rudinsky 1962, Waring and Pitman 1985). Investigators have used osmotic pressure as a criterion to determine tree susceptibility (Chalk and Bigg 1956, Furniss 1962, Rudinsky 1962). Other indicators for determining the susceptibility of trees have been proposed, such as the acidity of phloem sap, galvanoelectic measurement of the thickness of bark fibers, the starch content of the cells, (reviewed by Hendrickson 1965), oleoresin production and oleoresin exudation pressure (Vite and Wood 1981)). A small number of beetles can successfully colonize a stressed tree, but only mass attack by a large number can overcome the oleoresin defense of a healthy tree (Rudinsky 1962, Waring and Pitman 1985). Some investigators believe that a 'primary attraction' results from volatile compounds emanating from physiologically weakened trees (Person 1931, Heikkenen 1977).

On the other hand, other investigators believe that dispersing beetles land randomly on host and non-host trees, perhaps guided initially by visual cues (Gara et al. 1965). Whether or not the beetles colonize a tree depends on their acceptance of the tree as an appropriate host (Borden 1974).

Many other factors may be involved in the complex interactions between phytophagous insects and their host plants (Hanover 1975, Cates and Alexander 1982). Large bark beetles prefer large diameter host trees with thick phloem (Amman 1972, Berryman 1972, Cabrera 1978, Cates and Alexander 1982). Rudinsky (1962) and Coulson (1979) reported that competition (both interspecific and intraspecific) contributes significantly to bark beetle survival and may be the basis for pheromonal regulation of attack densities.

However, the ability of these beetles to discriminate among fallen trees of different species is poorly known. The amount of wood processed by these beetles has not been investigated.

The bluestain fungi, *Ophiostoma* (=*Ceratocystis*) spp., are associated with the scolytid bark and ambrosia beetles (Batra 1966, 1967, Abrahamson et al. 1967, Abrahamson and Norris 1969, 1970, Reid et al. 1967, Barras and Hodges 1969, Kok et al. 1970, Yearian et al. 1972, Safranyik et al. 1975, Whitney 1982, Paine 1984). The relationship between the beetles and their associated bluestain fungi is symbiotic (Franke-Grossmann 1964, Graham 1967, Berryman 1972, Birch 1978, Coulson 1979, Whitney 1982). The fungi are inoculated into weakened trees and logs by beetles during colonization (Batra 1967, Whitney 1982, Paine 1984, Paine and Birch 1983). In return, the fungi and other microbes apparently enhance the nutritional quality of the wood resources (Batra 1966, Barras and Hodges 1969, Whitney 1982). After the beetles leave the logs, the decomposition process continues through the activity of the fungi and other microflora

(Buchanan and Englerth 1940, Swift 1977, Whitney 1982, Coulson and Witter 1984).

Material and Methods

Site Description

The H. J. Andrews Experimental Forest is located 80 km east of Eugene, in lane County, Oregon, on the west slope of the Cascade Range in the Williamette National Forest. The climate of the Andrews Forest is maritime with wet, relatively mild winters and dry, warm summers. Mean annual precipitation is 2300 mm with 75% falling as rain between October and March. Soils are deep well-drained typic distrochrepts. Slope gradients range from 20%-60%.

Six sites were established in old-growth forests within the western hemlock zone (500-1100 m elevation) in fall of 1985 (Appendix I). These sites are dominated by 400-year-old Douglas-fir (Pseudotsuga mensiesii (Mirb.)Franco) commonly exceeding 80 m in height and 125 cm DBH. Western hemlock (Tsuga heterophylla (Raf.) Sarg.) and western redcedar (Thuja plicata Donn) are abundant at all sites, and Pacific silver fir (Abies amabalis (Dougl.)Forbes) is common above 1000 m (2 sites).

Log Selection

Four tree species, Douglas-fir, western hemlock, Pacific silver fir, and western redceder were selected for the experiment on the basis of their dominance of northwestern conifer forests and the range of decay resistance represented. The trees cut for this experiment met vigorous criteria concerning diameter, damage to bark cover, and the presence of decay. Diameters of the selected logs ranged between 45 cm and 60 cm. The logs were at least 5.3 m in length. Only logs with less than 10% of their bark missing were selected. Logs with any evidence of decay were rejected so that the initial conditions of the logs and their effect on colonizing heterotrophs could be controlled. At each site, logs of the four species were randomly placed side by side at 3 m spacing.

Beetle Density Measurement

In September 1986, after one year on the ground, one log of each species per site was sampled for colonization by ambrosia beetles, bark beetles and cerambycid beetles. On each log, two 0.5 m^2 surface area samples each from the top, side, and bottom of the log were examined.

Bark beetle densities were measured by counting the number of adult galleries in each sample after the bark was peeled from the log. The different species of bark beetles could be identified by specimens (if present) and by the characteristic gallery patterns. Some partial galleries and galleries without the adult bark beetle could not be ascribed to a particular beetle species.

Cerambycid beetles were represented by larvae which could not be identified to species. These were treated as a single functional group.

Ambrosia beetle entrances into the sapwood were obvious after the bark was removed. A sample area of 625 cm^2 was examined for ambrosia beetle entrances. Two samples each from the top, side and bottom of the log in each year were examined. Different ambrosia beetle species were determined by the diameter of the entry holes (Kinghorn 1957, Johnson 1958) except that the two species of *Gnathotrichus* could not be distinguished by gallery diameter.

In September 1987, the same sampling methods were used to measure beetle densities in order to account for new colonists. Because bark and ambrosia beetles are largely restricted to freshly dead logs, the samples from the second year also served to double the sample size for these insects.

Inner Bark Excavation

Bark beetles excavate galleries in the inner bark (phloem). Cerambycid beetles initially excavate the inner bark. In September 1986, bark samples were sealed in zip-lock plastic bags. The samples were returned to the laboratory at Oregon State University where length and width of the galleries at the inner bark-sapwood interface were recorded. Bark beetle and cerambycid galleries were distinguished by size and configuration. Because galleries did not have regular cross sectional areas, precise measurement of gallery volume was not possible. Rather, the inner bark surface area affected by galleries (A_g) was estimated using the formula:

$$A_g = L * W$$

where L is gallery length and W is gallery width. The percentage of inner bark surface area excavated (E) by bark beetles and cerambycid beetles was estimated by the formula:

$$E = (A_g / A_t) *100\%$$

Where A_t is total inner bark surface area.

Sapwood excavation

Ambrosia beetles excavate galleries in sapwood. Because ambrosia beetles were largely restricted to Douglas-fir and western hemlock and because sapwood dissection for gallery measurement was labor-intensive, only Douglas-fir and western hemlock logs from three sites were selected for estimation of volume excavated. One 8 cm thick section from each of the six logs was cut radially into quarters, which were dissected into 1 cm thick radial wedges. Dimensions of each quarter disk and the number of entry holes on the surface were recorded before dissection. Beetle galleries were traced from the entry holes through the gallery by using a length of steel wire. In order to locate brood chambers, the 1 cm wedges frequently were dissected. The length and diameter of both adult galleries and brood chambers were recorded. The volume of an individual gallery (V_g) was calculated by the formula:

$$V_g = \pi r_g^2 * L_g$$

Where r_g is radius of the gallery, and L_g is the length of the gallery. The total volume excavated by each species of ambrosia beetle (V_s) on each log species could be estimated by the formula:

$$V_s = \sum_{i=1}^{N} V_g$$

Where V_g is the volume of an individual gallery and N is the number of each ambrosia beetle species on each log species.

The total sapwood volume of each log (V_t) was calculated by the formula:

$$V_t = (\pi r_o^2 * L) - (\pi r_i^2 * L)$$

Where r_o is the outer radius of the sapwood, r_i is the inner radius of the sapwood and L is the length of log. The percent sapwood volume excavated (E) by ambrosia beetles was calculated by the formula:

$$E = V_s / V_t * 100\%$$

Ambrosia Beetle Emergence

Because ambrosia beetle brood emerge from the parent entry hole, reproductive success can be measured by the number of emerging beetles. Two log species, Douglas-fir and western hemlock, at two sites were used to measure the number of ambrosia beetles produced per gallery. Logs were cut from trees felled in March, 1987. The logs were heavily attacked by ambrosia beetles during April and June. Plastic petri dishes (10 cm diam.) were used to cover individual entry holes to galleries (Hosking 1972, Shore et al. 1987). The base of each petri dish had a small, drilled hole which was aligned with the gallery entrace. The surface of bark was first smoothed with a draw knife, and a small piece of clay was used to ensure a seal between the dish and the log surface. The petri dish was secured to the log by an elastic band stretched over the lid between two nails placed close to the edge on opposite sides of the petri dish (Shore et al. 1987).

Twenty petri dishes were distributed between logs of the two species. Galleries were selected randomly with regard to beetle species and location on the log. The dishes were emptied periodically from 1 July through September. Parent beetles could not be distinguished from new brood in the field. Hence, the recorded beetle production included both the brood and any parents which survived to leave the gallery (Dyer 1963).

Data Analysis

The Chi-square test was used to analyze statistical significance of treatment differences. The data analysis was conducted using SAS statistical software. (SAS Institute, Inc. 1985).

Results

Host Selection

Field observation showed that almost all bark beetles and ambrosia beetles entered the logs through crevices in the bark, as indicated by frass on the surface of the bark. Ambrosia beetles excavating the sapwood produced white frass which could be distinguished from the brown frass produced by bark beetles excavating inner bark.

Each beetle species showed distinct preferences for the four conifer log species. Ambrosia beetles are likely to attack logs of many conifer log species (Bletchly and White 1962, Chapman et al. 1963, Dyer and Chapman 1965), but *T. lineatum* and *Gnathotrichus* spp. in this study clearly preferred Douglas-fir and western hemlock to silver fir or western redcedar. About 90% of *Trypodendron* (Fig 1.) and 75% of *Gnathotrichus* (Fig 2.) attacked these two log species in roughly equal proportions. The Chi-square test showed that the attack density on these two log species was significantly higher than on Pacific silver fir and western redcedar ($P<0.001$). *X. saxeseni* attacked all four log species at low densities, apparently without discrimination (Fig 3).

About 75% of the ambrosia beetles on Douglas-fir and western hemlock were *T. lineatum*. About 68% of ambrosia beetles on Pacific silver fir and 33% on western redcedar were *T. lineatum* (Fig. 3).

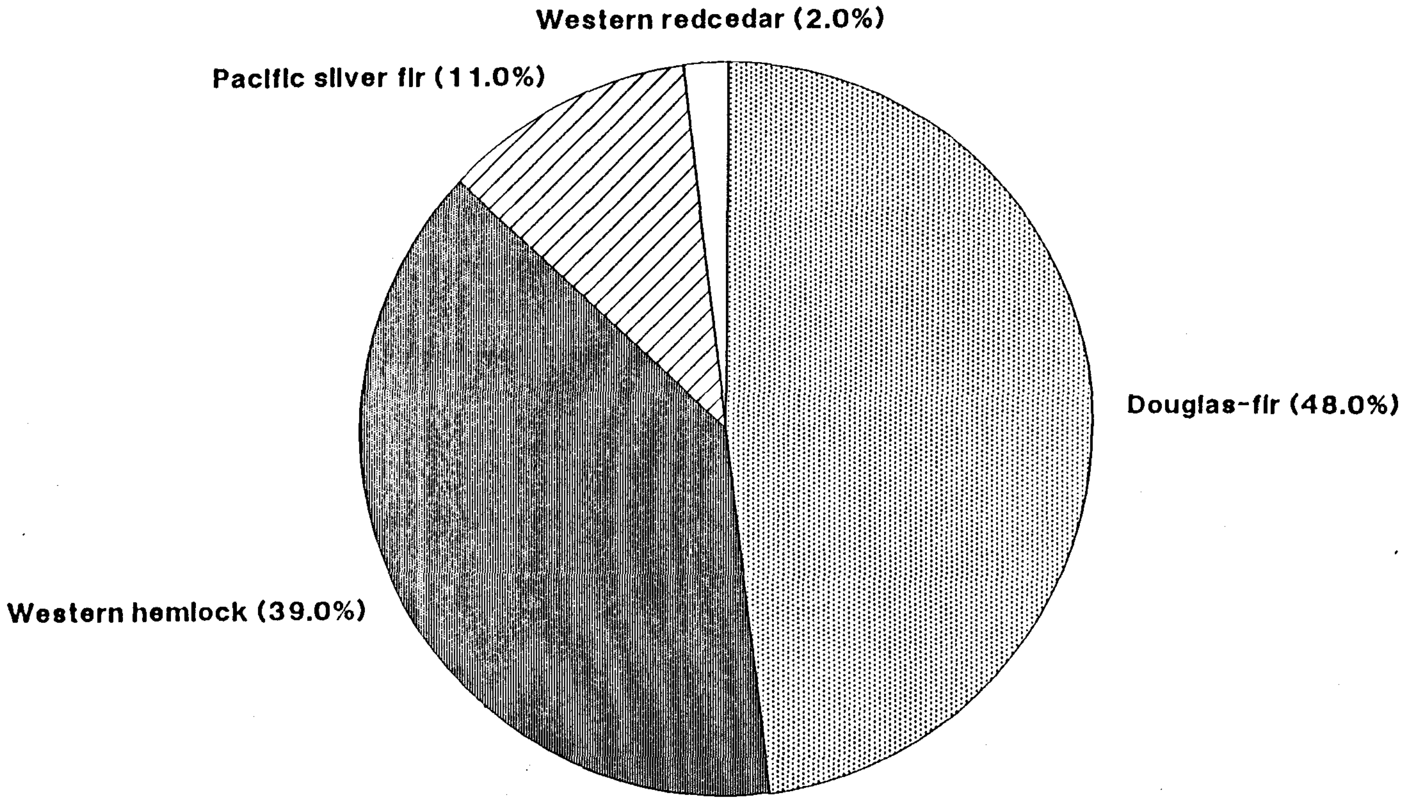

Fig 1. The percentage distribution of T. lineatum on four conifer species in western Oregon in 1987.

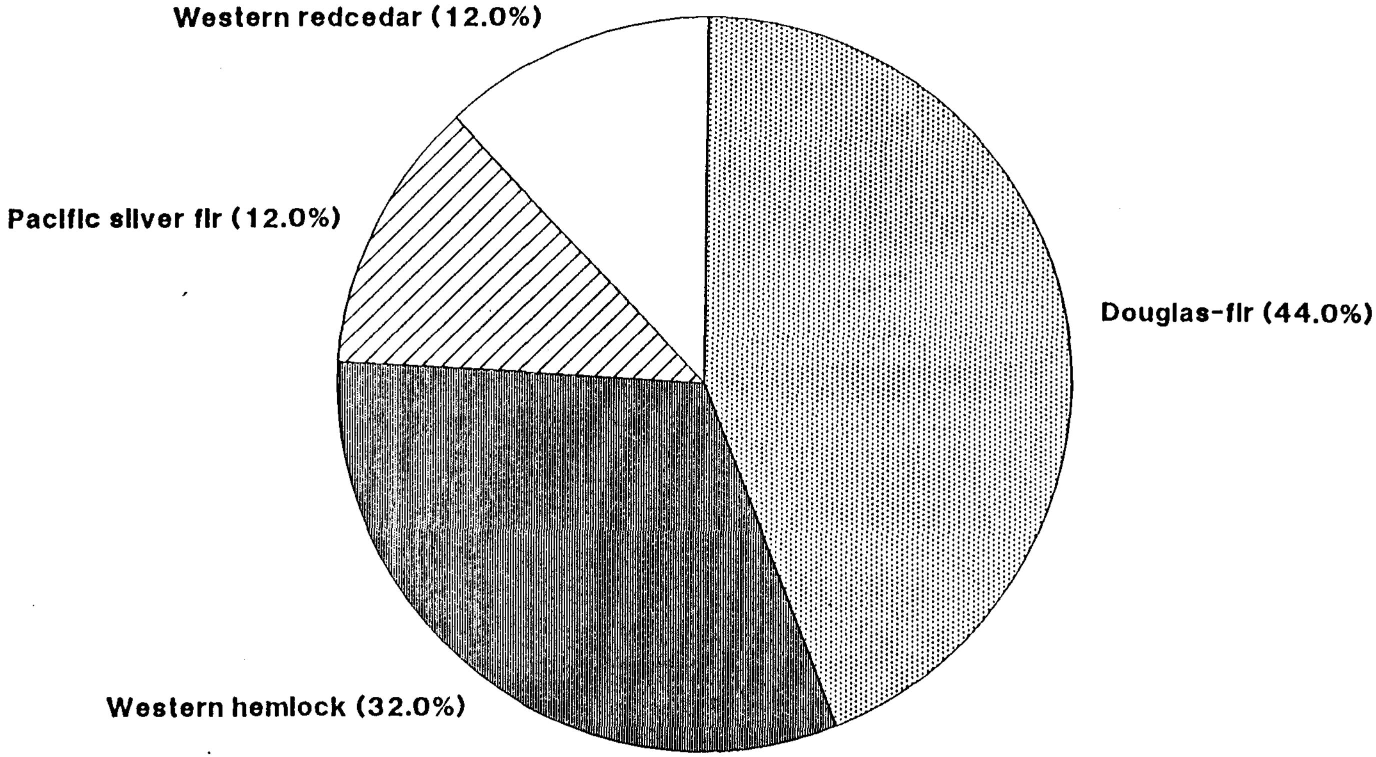

Fig 2. The percentage distribution of <u>Gnathotrichus</u> spp. on four conifer species in western Oregon in 1987.

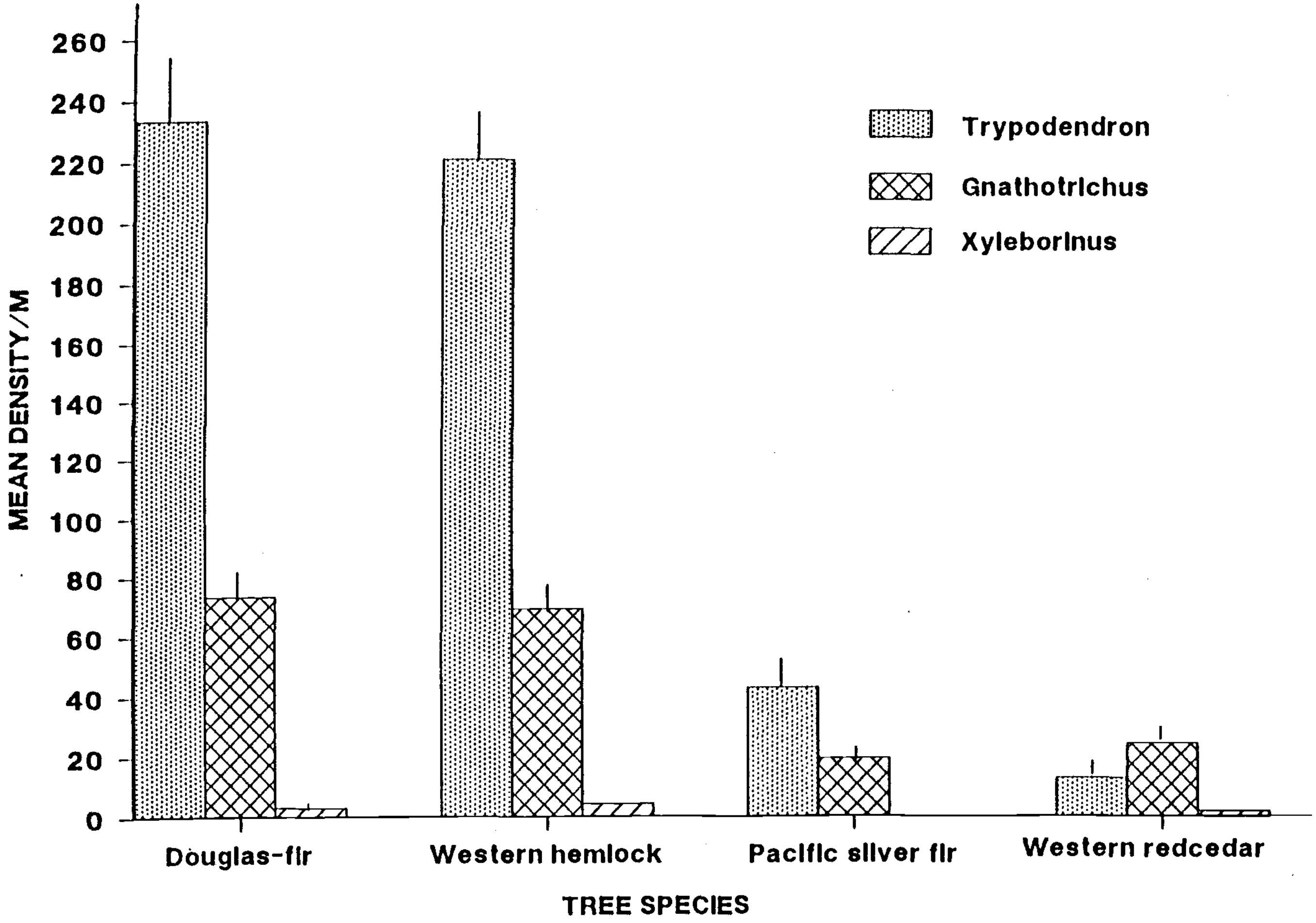

Fig 3. Combined (two years) mean density of ambrosia beetles on logs of four conifer species in western Oregon.

Investigation showed that ambrosia beetle colonization was essentially limited to the first year. T. lineatum did not attack logs which had been caged to exclude beetles during the first year but were exposed to beetle attack during the second year. Gnathotrichus and Xyleborinus were observed attacking logs in the second year, but their numbers were small. The total ambrosia beetle population did not differ significantly between the two years.

Bark beetles showed greater host specificity than did the ambrosia beetles. Douglas-fir attracted Dendroctonus pseudotsugae Hopkins and Dryocoetes autographus Ratzeburg, western hemlock attracted D. autographus, Pacific silver-fir attracted Pseudohylesinus sericeus (Mannerheim), and western redcedar attracted Phloeosinus spp.. Though the beetle species were different, Douglas-fir and Pacific silver-fir had significantly higher bark beetle densities than did western hemlock and western redcedar ($P<0.001$) (Fig. 4).

The number of cerambycid galleries was significantly higher in Pacific silver fir than in the other tree species in 1986 (Fig 5). Cerambycid density increased significantly in western hemlock and equaled densities in Pacific silver fir in 1987. Cerambycid beetle density also increased significantly in western redcedar in 1987. Densities did not increase in Douglas-fir (Fig 5). The densities of cerambycid galleries in western hemlock and Pacific silver fir were significantly higher than in redcedar, which had higher attack densities than did Douglas-fir in 1987 (P<

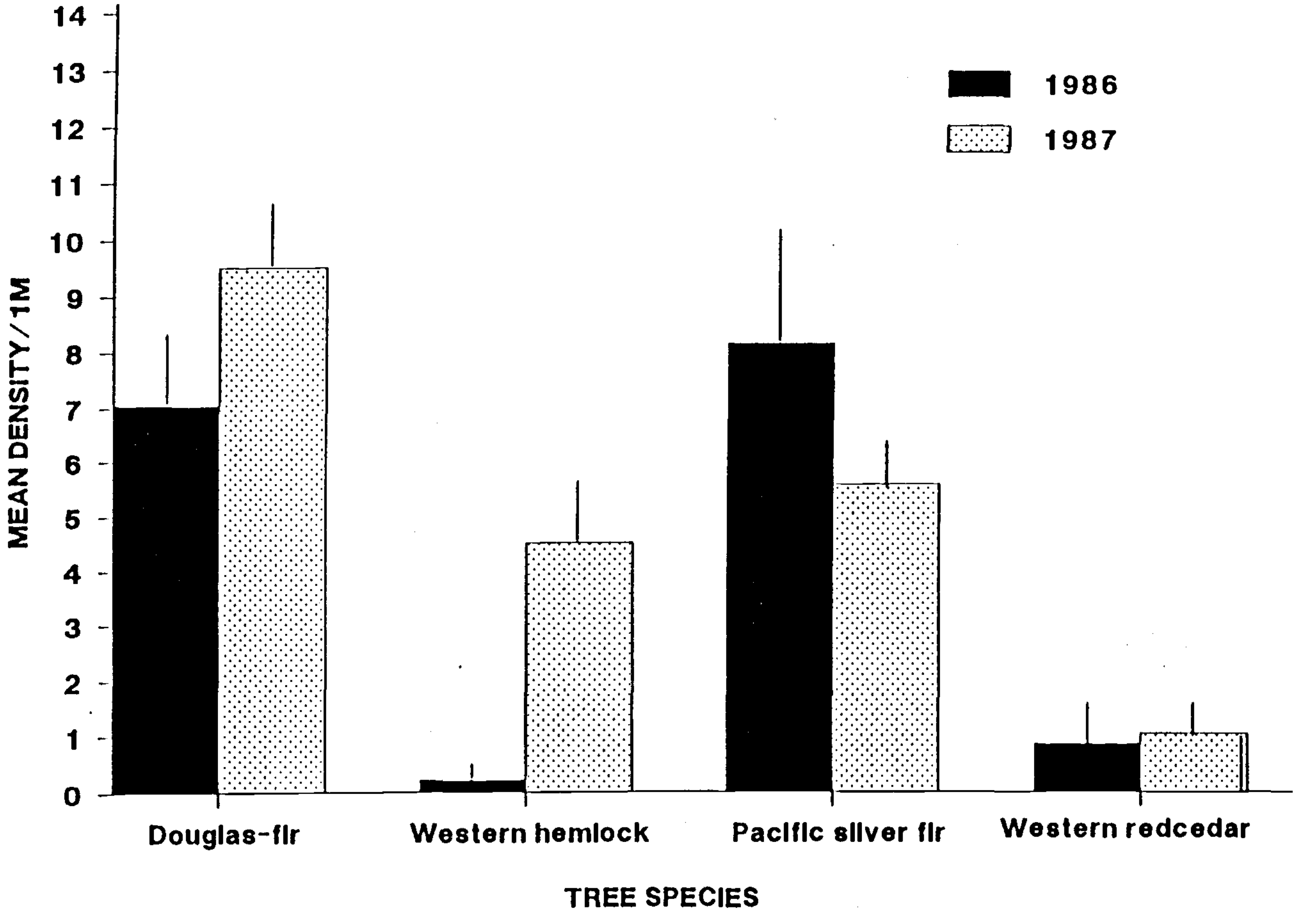

Fig 4. Mean numbers of bark beetles on logs of four conifer species in 1986 and 1987.

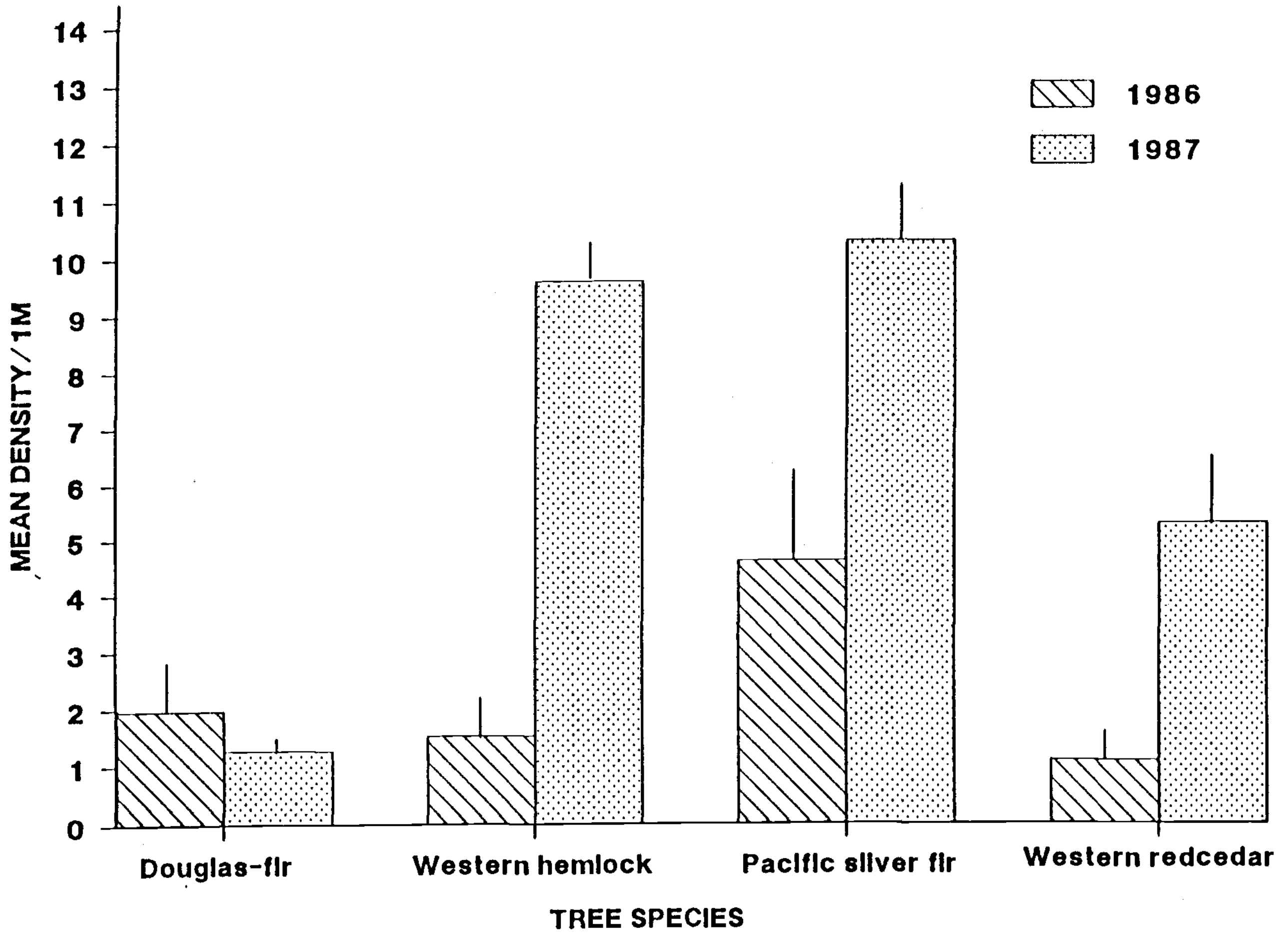

Fig 5. Mean numbers of cerambycid beetles on logs of four conifer species in 1986 and 1987.

0.01) (Fig. 5). Although cerambycids were considered as a functional group because the larvae are difficult to identify to species, different log species likely are preferred by different cerambycid species.

Chi-square tests showed that position on the log had no significant effect on beetle distribution, though T. lineatum and Gnathotrichus spp. tended to have higher density on the side vs. top or bottom positions (Table 1).

Site effects also were tested by Chi-square. The only significant difference between sites was for ambrosia beetle density which was higher at site 3 than at the other sites (Fig. 6). One explanation was that ambrosia beetles were more abundant at site 3, possibly due to previous salvage operations near this site. However, the effect of site was minor compared to other variables.

Beetle Excavation

Ambrosia beetle galleries in Douglas-fir logs and western hemlock logs did not extend into the heartwood, as reported by McLean (1985). Mean sapwood thickness was 4.2 cm in Douglas-fir and 8.8 cm in western hemlock. The depth of penetration by T. Lineatum was 2.5-3.1 cm in Douglas-fir and 3.4-3.8 cm in western hemlock. Gnathotrichus spp. penetrated to depths of 2.8-3.4 cm in Douglas-fir and 6.8-7.7 cm in western hemlock.

The average gallery length of T. lineatum was 9.87 cm in Douglas-fir (Table 2) and was 12.38 cm in western hemlock

Table 1.

Beetle attack density in 1 m^2 samples by positions on coniferous logs in H. J. Andrews National Forest Western Oregon.

	Top	side	Bottom	Total
Douglas-fir				
Trypodendron	155	237	155	547
Gnathotrichus	104	149	99	352
Xyleborinus	5	6	5	16
Bark beetles	7	8	14	29
Cerambycids	2	1	1	4
Western hemlock				
Trypodendron	150	188	127	465
Gnathotrichus	84	129	52	265
Xyleborinus	6	7	8	21
Bark beetles	4	5	4	13
Cerambycids	10	9	10	29
Pacific silver fir				
Trypodendron	37	54	30	121
Gnathotrichus	26	34	36	96
Xyleborinus	1	1	1	3
Bark beetles	4	5	8	17
Cerambycids	12	11	9	32
Western red cedar				
Trypodendron	9	13	4	26
Gnathotrichus	25	45	27	97
Xyleborinus	6	1	2	9
bark beetles	1	0	2	3
Cerambycids	8	5	4	17

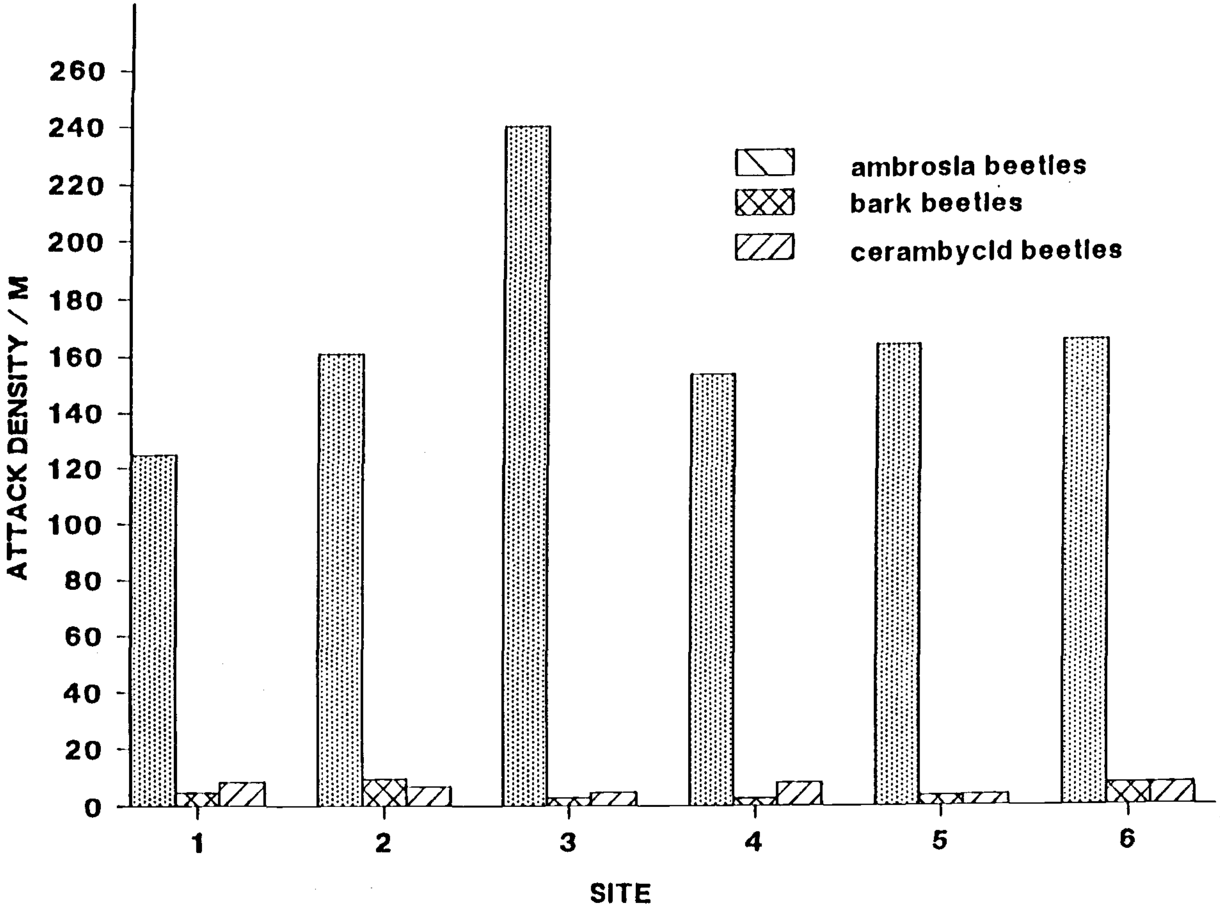

Fig 6. Mean beetle attack density by site.

Table 2.

Mean gallery length and percentage sapwood volume excavated by ambrosia beetes in Douglas-fir during the first year of decomposition in western Oregon.

	Trypodendron	*Gnathotrichus*	*Xyleborinus*
Gallery length(cm)	9.87	17.83	17.13
Volume/Gallery(cm^3)	0.33	0.24	0.11
Gallery Density/log	2500	270	12
Sapwood Excavated(%)	0.16	0.01	0.00

(Table 3). Each *T. lineatum* removed about 0.33 cm^3 of sapwood from Douglas-fir and about 0.35 cm^3 of sapwood from western hemlock (Tables 2 and 3). Gallery volumes multiplied by the number of galleries per log provided estimates of the total sapwood volume processed by ambrosia beetles. About 0.2% of Douglas-fir and western hemlock was excavated by ambrosia beetles (Tables 2 and 3).

About 7.6% of the inner surface area of Douglas-fir phloem and 6.8% of the inner surface area of Pacific silver fir phloem was excavated by bark beetles in the first year (Table 4). In addition about 2.3% of the inner surface area of Pacific silver fir phloem was excavated by cerambycid beetles (Table 5).

Ambrosia Beetle Emergence

T. lineatum adult progeny began to emerge by the beginning of July, which indicated a development period of 9-10 weeks from time of attack to emergence (Borden and Fockler 1973, Shore et al. 1987). Peak emergence occured in the first 3-4 weeks of July. *Gnathotrichus* adult progeny began to emerge in July. Peak emergence occured in mid August.

Of the 20 galleries monitored, 16 produced emerging beetles. The two galleries from each tree species which did not yield beetles could not be positively ascribed to beetle species. Overall mean emergence (+ SE) from Douglas-fir was 1.78 (0.49) and from western hemlock was 2.18 (0.57). The

Table 3.

Mean gallery length and percentage sapwood volume excavated by ambrosia beetles in western hemlock during the first year of decomposition in western Oregon.

	Trypodendron	*Gnathotrichus*	*Xyleborinus*
Gallery length(cm)	12.38	52.32	3.7
Volume/gallery(cm^3)	0.35	0.68	0.02
Gallery density/log	2700	480	16
sapwood excavated(%)	0.18	0.06	0.00

Table 4.

Mean bark beetle density (#/m^2) and percentage phloem excavated by bark beetles in four conifer log species during the first year of decomposition in western Oregon.

Tree species	Beetle Density(#/m^2)	Phloem excavated(%)
Douglas-fir	7.05	7.6
Western hemlock	0.22	0.13
Pacific silver fir	8.16	6.8
Western Redcedar	0.88	0.42

Table 5.

Mean cerambycid beetle density (#/m^2) and percentage phloem excavated by cerambycid beetles in four conifer log species during the first year of decomposition in western Oregon.

Tree species	Beetle Density(#/m^2)	Phloem excavated(%)
Douglas-fir	1.98	0.05
Western hemlock	1.54	0.18
Pacific silver fir	4.63	2.3
Western redcedar	1.10	0.16

mean number of *T. lineatum* emerging from successful galleries was 2.29 (0.47) for Douglas-fir (7 galleries) and 3.14 (0.63) for western hemlock (7 galleries), much lower than the 11-13 per successful gallery reported by Shore et al.(1987) and Dyer (1963) and lower than 4-5 per gallery reported by Borden & Fockler (1973). Mean number of *Gnathotrichus* spp. emerging from successful galleries was 1.0 for western hemlock (2 galleries); no *Gnathotrichus* spp. emerged from Douglas-fir. These data indicate declining population in these spring-felled logs.

Discussion

This study indicated that tree species was the most important factor determining patterns of colonization by bark beetles and ambrosia beetles. Douglas-fir and western hemlock were preferred by _T_. _lineatum_ and _Gnathotrichus_ spp.(Fig. 3). Douglas-fir and Pacific silver fir were preferred by bark beetles and cerambycids (Figs. 4 and 5).

Felled and dying trees of appropriate species contain primary olfactory attractants for both male and female bark beetles and ambrosia beetles(Francia and Graham 1967, Rudinsky and Daterman 1964a, wood 1982). Chapman (1963) reported that many scolytids select hosts from odors released in the field. The Douglas-fir beetle, _D_. _pseudotsugae_ was attracted only by Douglas-fir odors, _Gnathotrichus_ spp. was attracted almost equally by Douglas-fir and western hemlock, and _T_. _lineatum_ was attracted by Douglas-fir and possibly western hemlock (Chapman 1963). My study suggested that Douglas-fir and western hemlock were equally attractive to _T_. _lineatum_ and _Gnathotrichus_ spp. In contrast to the host selection bahavior observed at Cowichan lake, BC.(Chapman 1963), _X_. _saxeseni_ apparently attacked the four log species indiscriminately (Fig. 3). This may be due to a very small and randomly distributed _X_. _saxeseni_ population. Pacific silver fir and western redcedar, which are not considered attractive to _Trypodendron_ and _Gnathotrichus_ (Chapman 1963), were still attacked by a few beetles of both species. This may have been due to spillover of the population from logs saturated with colonizing beetles. Soon after successful invasion, pioneer beetles begin to produce pheromones which attract large numbers beetles and cause mass invasion of the source tree as well as neighboring trees located within the perimeter of attraction (Rudinsky 1966, Coulson 1979).

Development of T. lineatum from egg stage to brood emergence takes 8-14 weeks (Prebble & Graham 1957, Annila et al. 1972). Emergence from both Douglas-fir and western hemlock peaked in late July, as found in previous studies (Chapman & Neitsch 1959, Dyer & Kinghorn 1961, Dyer 1963, Rudinsky & Daterman 1964a, Dyer & Chapman 1965, Annila et al. 1972). Emergence of Gnathotrichus spp. peaked in August, two to three weeks later than T. lineatum.

Buchanan and Englerth (1940) stated that losses to insects exceeded losses to decomposer microorganisms only during the initial period log decomposition. However, insect contribution to log decomposition included introduction of fungi and microfauna through the bark barrier (Whitney 1982). Bark beetles and ambrosia beetles are known to depend on introduced mutualistic microflora for nutritional enhancemant of wood tissues (Barras and Hodges 1969, Batra 1967, Whitney 1982).

Although ambrosia beetles did not remove a substantial amount of sapwood (<0.2%), their galleries affected virtually the entire sapwood volume from the standpoint of fungal inoculation. Bark beetles, on the other hand, accounted for substantial excavation of inner bark. Excavation by D. pseudotsugae and D. autographus in Douglas-fir amounted to 7.6% of inner bark surface area and excavation by P. sericesus in Pacific silver fir amounted to 6.8% (Table 3.). This indicated that fragmentation and microbial inoculation of inner bark by beetles may play an important role in initial decomposition and leaching losses of these two log species. Pacific silver fir phloem also was extensively excavated by cerambycid beetles which accounted for channelization of an additional 2.3% of phloem surface area. This group will remain active and account for continued excavation through time.

Although quantitatively small, beetle excavation accelerates penetration of wood by decomposer micro-organisms and thus is functionally important to the long-term pattern of wood decomposition.

Summary

1. The purpose of this investigation was to study host selection by bark and ambrosia beetles, to estimate the volume of log material removed by bark and ambrosia beetles and to estimate beetle reproductive potential.

2. The investigation was conducted at the H. J. Andrews Experimental Forest, western Oregon during 1986-1987, the first two years of decomposition of experimental logs.

3. Ambrosia beetles, T. lineatum and Gnathotrichus spp., preferred Douglas-fir and western hemlock. Bark beetles were relatively more host specific and different log species attracted different bark beetle species.

4. Trypodendron was responsible for removal of about 0.16% of sapwood from Douglas-fir and about 0.18% of sapwood from western hemlock. Gnathotrichus was responsible for additional removal of about 0.01% sapwood from Douglas-fir and about 0.06% from western hemlock.

5. Bark beetles, D. pseudotsugae and D. autographus, excavated about 7.6% of phloem surface area in Douglas-fir. P. sericesus excavated about 6.8% of phloem surface area in Pacific silver fir.

6. Cerambycid beetles preferred Pacific silver fir and accounted for additional excavation of about 2.3% of phloem surface area in this species, during the first year of log decomposition.

7. The average emergence of ambrosia beetle brood was 1.78 from Douglas fir and 2.18 from western hemlock, and suggesting a declining population in these spring-felled logs.

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Appendix

Appendix I

Site Description

Site	Elevation	Location	Map coordinates
1	1000M	end of the 327 road.	T15S,R5E,sect. 14NE
2	850M	northwest side of the 324 road.	T15S,R5E,sect. 14SW
3	490M	north side of the 410 road.	T15S,R5E,sect. 28NW
4	800M	west side of the 350 road.	T15S,R5E,sect. 25NW
5	1050M	southwest side of the 354 road.	T15S,R6E,sect. 19SW
6	850M	south side of the 1506 road	T15S,R6E,sect. 29SW