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THE FIR ENGRAVER BEETLE, A SERIOUS ENEMY OF WHITE FIR AND RED FIR

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INTRODUCTION

The fir engraver beetle (*Scolytus ventralis* Lec.) is a major cause of widespread damage and destruction to our western forests of fir. Trees varying in age from poles to mature timber are attacked by it and are often killed during a single season. Many trees, weakened through successive attacks, die slowly over a period of years. Others may survive the injury, but develop defects and rots which render timber unfit for commercial use.

While the fir engraver beetle is not a new pest, its activity and aggressiveness have greatly increased during the past decade, especially in the mountainous areas of California and Oregon. Sporadic outbreaks have occurred in certain localities two or three times since 1928, but no general epidemics have extended over very large areas. A conservative estimate, based on surveys and observations since 1924, places the destruction of merchantable fir in California alone at about 15 percent of the stand and damage at an additional 25 precent.

Like most other species of bark beetles, the fir engraver beetle injures its host by mining along the cambium layer of the main trunk, where eggs are deposited and broods develop to destroy large areas of the most vital part of a tree. It attacks most commonly the upper third of the trunk, although attacks on the lower bole are by no means rare. The upper stem, under 4 inches in diameter, is seldom attacked. Although many other species of bark beetles cannot develop successful broods without first killing the tree, the fir en-

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graver beetle, possibly on account of the association of other organisms, is able to attack and establish broods when only a portion of the cambium area of the trunk has been killed.

Aside from its taxonomic position and description in the literature,[1 2 3] detailed knowledge of this important forest insect is entirely lacking. Specific information is of great importance to foresters, entomologists, and those interested in combating forest insects. This circular presents as fully as possible the results of studies made from 1928 to 1932, inclusive, by the Berkeley laboratory of the Bureau of Entomology and Plant Quarantine. Abundance of available material in the central Sierra Nevada section of California was particularly favorable to this work.

HOSTS AND DISTRIBUTION

Periodic outbreaks of this insect occur over the entire range of fir trees in the West. Nearly all species of fir are attacked, but white fir (*Abies concolor* Lindley and Gordon), lowland white fir (*A. grandis* Lindl.), and California red fir (*A. magnifica* A. Murray) are the most susceptible. The fir engraver beetle has also been collected from Alpine fir (*A. lasiocarpa* (Hook.) Nutt.), Douglas fir (*Pseudotsuga taxifolia* (Lam.) Britton), Engelmann spruce (*Picea engelmanni* Engelm.), and mountain hemlock (*Tsuga mertensiana* (Bongard) Sargent). It has been found in British Columbia, Washington, Montana, Idaho, Utah, Oregon, California, Arizona, New Mexico, and Nevada.[4]

LIFE HISTORY AND HABITS OF THE BEETLE

ADULTS

The adult is black, shining, from 3 to 5 mm long, and far more active than most bark beetles. In lateral profile the ventral part of the abdomen is incurved, as shown in plate 1, *A*. Although the beetles are found commonly in fir timber during July and August, and less frequently in June and September, large numbers are rarely observed in flight.

ATTACKS AND MATING HABITS

Attacks are made along the main trunk, usually in roughened bark surrounding the bases of branches. When a suitable spot has been selected for an entrance hole, the female rotates about it and cuts bits of bark away. Within from 36 to 48 hours the hole is extended at an upward slant to the cambium layer. The surfaces of the sapwood and inner bark are then deeply grooved to form a nuptial chamber large enough to accommodate two beetles.

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[1] LECONTE, J. L. APPENDIX. *In* Zimmermann, C., Synopsis of the Scolytidae of America north of Mexico. Amer. Ent. Soc. Trans. 2: 150–178. 1869. (See p. 167.)

[2] SWAINE, J. M. CANADIAN BARK-BEETLES. PART II. A PRELIMINARY CLASSIFICATION, WITH AN ACCOUNT OF THE HABITS AND MEANS OF CONTROL. Canada Dept. Agr., Ent. Branch, Bull. 14, pt. 2, 143 pp., illus. 1918.

[3] BLACKMAN, M. W. A REVISIONAL STUDY OF THE GENUS SCOLYTUS GEOFFROY (ECCOPTOGASTER HERBST) IN NORTH AMERICA. U. S. Dept. Agr. Tech. Bull. 431, 31 pp. 1934.

[4] The writer makes grateful acknowledgment of his indebtedness to M. W. Blackman, senior entomologist, and F. P. Keen, entomologist, Bureau of Entomology and Plant Quarantine, and to Ralph Hopping, entomologist, Entomological Branch, Canada Department of Agriculture, for information on the distribution and abundance of *Scolytus ventralis* and the habits of related species.

Aside from the entrance holes, successful beetle activity is indicated by reddish-brown borings in bark crevices and cobwebs at the junction of branches with the trunk. Pitch tubes, characteristic of most attacks by *Dendroctonus*, are never found in fir, but often fir engraver attacks are indicated by scattered streamers of balsam on the upper bole. The male beetle assists in removing debris soon after the female has bored in a short distance from the outside. Before that time the male may have mated with several females, but eventually he selects a permanent mate, after which he remains with her, mating many times during the egg-laying period. From 2 to 3 weeks before the egg-laying period is completed the male abandons the female entirely. His later habits are unknown.

CONSTRUCTION OF EGG GALLERIES

Excavation of egg galleries by the female is begun immediately after the nuptial chamber has been completed. Two horizontal galleries, cutting deeply both the sapwood and inner bark surfaces, are extended in opposite directions from the upper portion of the nuptial chamber (fig. 1 and pl. 1, *B*, *C*). When completed, each gallery is from 2 to 6 inches long, with the nuptial chamber at or near the center. Both galleries are started within the first week, and construction of each continues alternately throughout the entire egg-laying period of 5 to 7 weeks.

As soon as each gallery is extended beyond one-eighth inch from the nuptial chamber, tiny niches, spaced 1 to 1.5 mm apart, are excavated along the cambium layer on each side. One egg is deposited in each niche and packed tightly with frass. From 100 to 300 eggs are deposited in the average completed gallery. The female then backs into the entrance hole and soon dies. This blocks the opening and apparently serves in some degree to prevent the entrance of predacious and parasitic enemies.

DEVELOPMENT OF CAMBIUM STAIN

Within from 4 to 6 days after an egg gallery is begun there appears a yellowish-brown discoloration of the cambium layer, extending vertically from each side of the gallery (fig. 1). The discoloration continues to spread both upward and downward, indicating the dying of large areas of cambium. It is well established by the time the first eggs have hatched and continues to spread in advance of the feeding larvae. The cause is a fungus, which has been studied in detail by Wright,[5] of the Division of Forest Pathology, Bureau of Plant Industry, by whom it was determined as a species of *Trichosporium*.

Although constantly associated with newly established attacks and introduced by *Scolytus* adults, the role of the organism in relation to fir engraver broods has not yet been determined. However, it has a tendency to dry out the cambium layer, and this may be an important factor in the successful establishment of broods.

[5] WRIGHT, E. TRICHOSPORIUM SYMBIOTICUM, N. SP., A WOOD-STAINING FUNGUS ASSOCIATED WITH SCOLYTUS VENTRALIS. Jour. Agr. Research 50: 525–538, illus. 1935.

Long periods of attack and egg laying account for apparently retarded development of a portion of the brood, which may extend over a second winter. New attacks on green trap logs have been found to continue over a period of from 4 to 6 weeks, but most commonly persist for about 3 weeks. The combination of prolonged periods of attack and egg laying results in considerable overlapping of broods and causes some confusion about the age of the brood and the duration of the cycle.

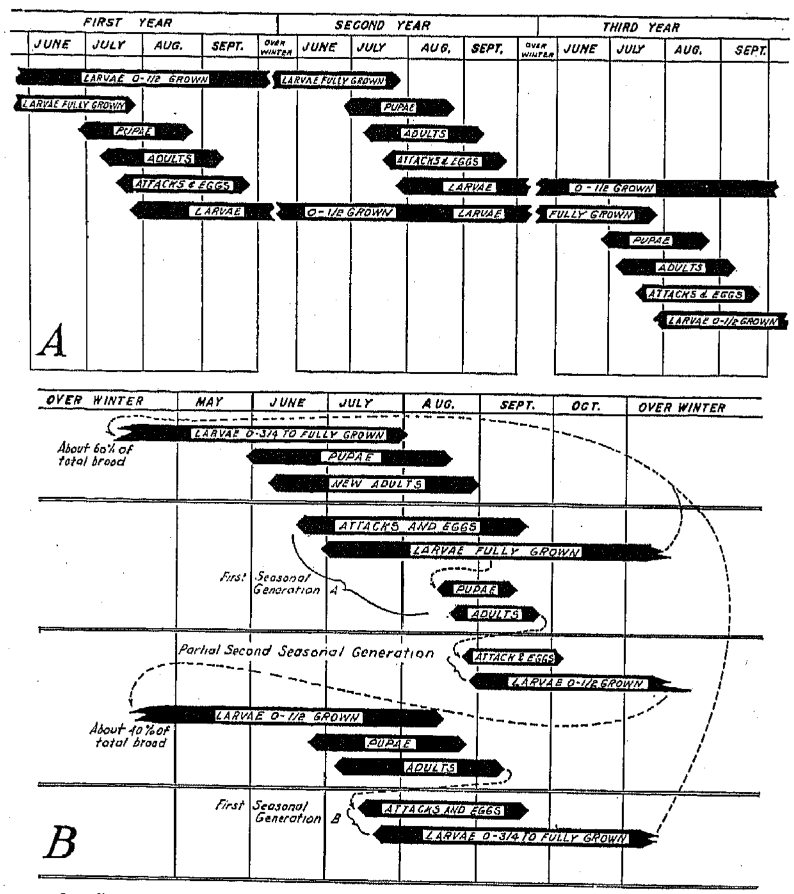


FIGURE 2.—Seasonal history of *Scolytus ventralis* in the Sierra Nevada Mountains: *A*, Minimum rate of development at 6,000- to 8,000-feet elevation; *B*, maximum rate of development at 3,500- to 6,000-feet elevation.

CHARACTER OF DAMAGE

FADING

Successful fir engraver beetle activity is manifested by fading foliage of branches adjoining the main bole in the vicinity of the point of attack. Successful attacks started during July and early in August cause the foliage to turn yellowish green within from 4 to 6 weeks and from sorrel to reddish brown some time later. Attacks initiated later in the summer do not often result in foliage changes until winter or early in the spring of the following year. Conspicuous fading branches scattered among the green ones indicate that the cambium layer surrounding the bases of these branches has been girdled. Girdling of the cambium layer surrounding the trunk causes the top to fade above the girdled area. If the main trunk is girdled at or below the basal part of the crown, the entire crown fades at one time.

EMBEDDED SCARS

Injured areas along the main trunk readily heal over if the trunk has not been completely girdled, and within a few years evidence of the attack is buried in the wood by the overgrowth of the annual rings following the year of attack (pl. 2). External evidences of old attacks are often found as swellings or abnormal irregularities of the outer bark. Deeply embedded scars as far back as 1865 have been recognized in certain studies carried out in 1929 by J. M. Miller, senior entomologist, Bureau of Entomology and Plant Quarantine.

Figure 3 is a drawing from a specimen taken from a tree felled near Pinecrest, Calif. This specimen broke irregularly to expose seven different attacks from 1888 to 1929, the last of which killed the tree. Egg galleries and fungus stain were preserved perfectly on each scar. In cross section deeply stained annual rings mark the years of attack.

TOP KILLING

Top killing, while probably no more frequent than partial killing of the trunk, is far more conspicuous. Fading and reddish-brown tops, old spike tops, and secondary leaders forming new tops are commonly found (pl. 3). Wide variations occur in the extent of the crown killed, often reaching as high as 90 percent of the total length. Different ages of top killing frequently occur in the same tree over a period of several seasons. Some trees are killed by successive attacks by fir engraver beetles, while others are killed by secondary insects. Weakened mature trees are especially attractive to secondary bark- and wood-boring beetles.

TYPES OF INJURY

Fir engraver beetle injury or killing is divided into three distinct recognizable types. Type 1 includes all top killing and type 2 considers only trees injured in scattered areas along the bole. Type 3 includes all trees entirely killed and is divided into three subtypes, A, B, and C, according to age of host, infestation, and time required to kill. While the fir engraver beetle is primary in all types, the Sierra fir borer (*Tetropium abietis* Fall) is a very important factor in killing old and mature trees in type 3, B and C. A more detailed description of each type is found in table 1.

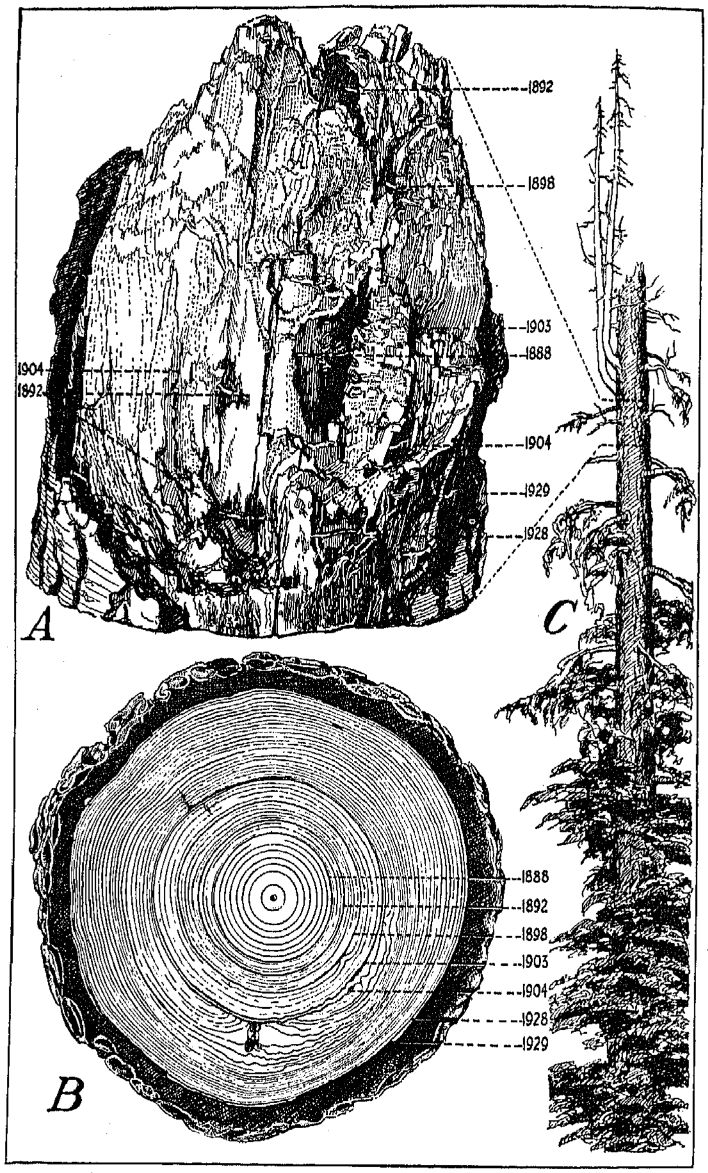
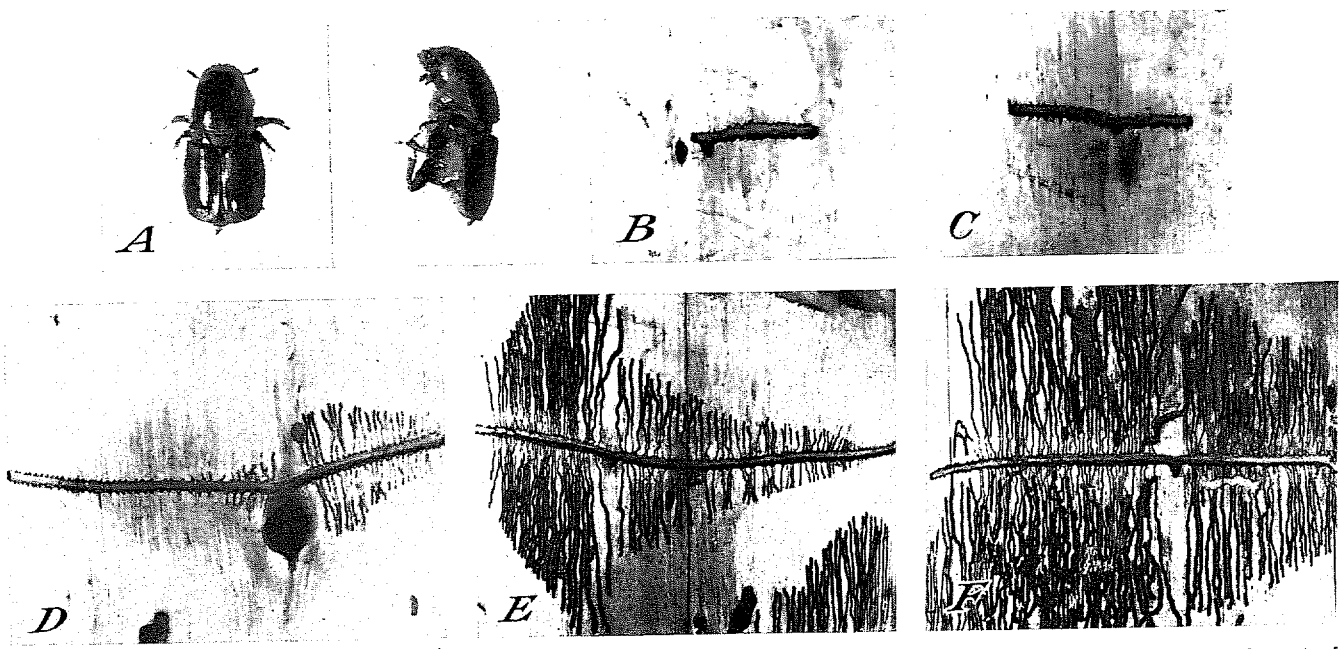
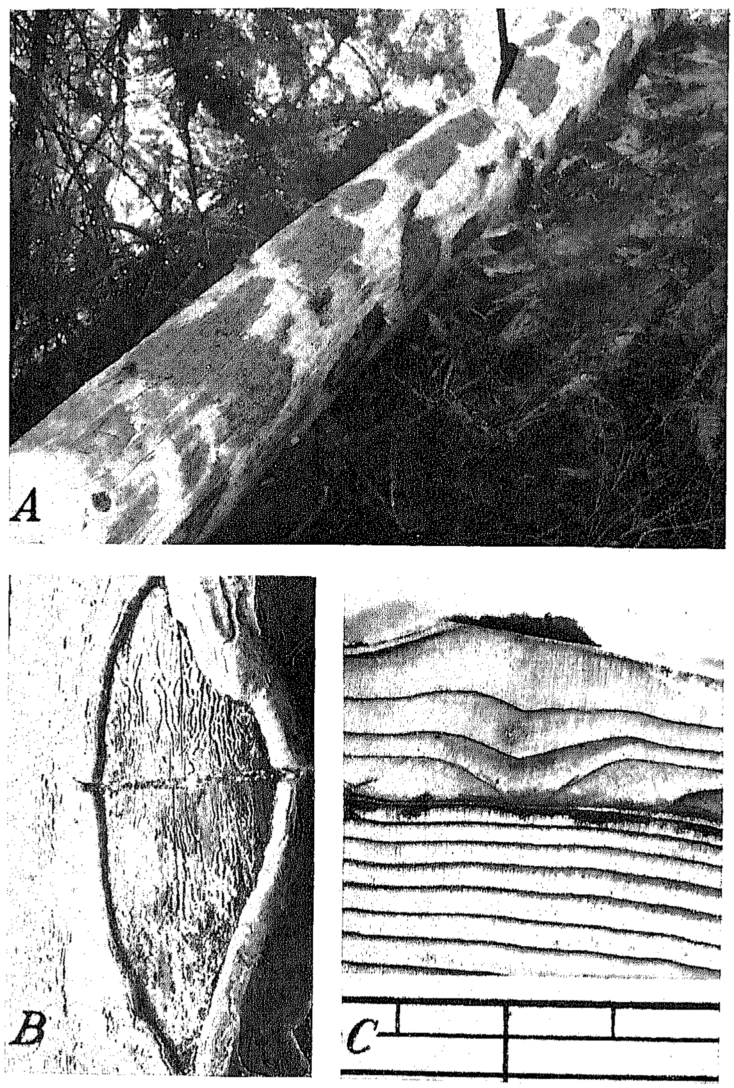


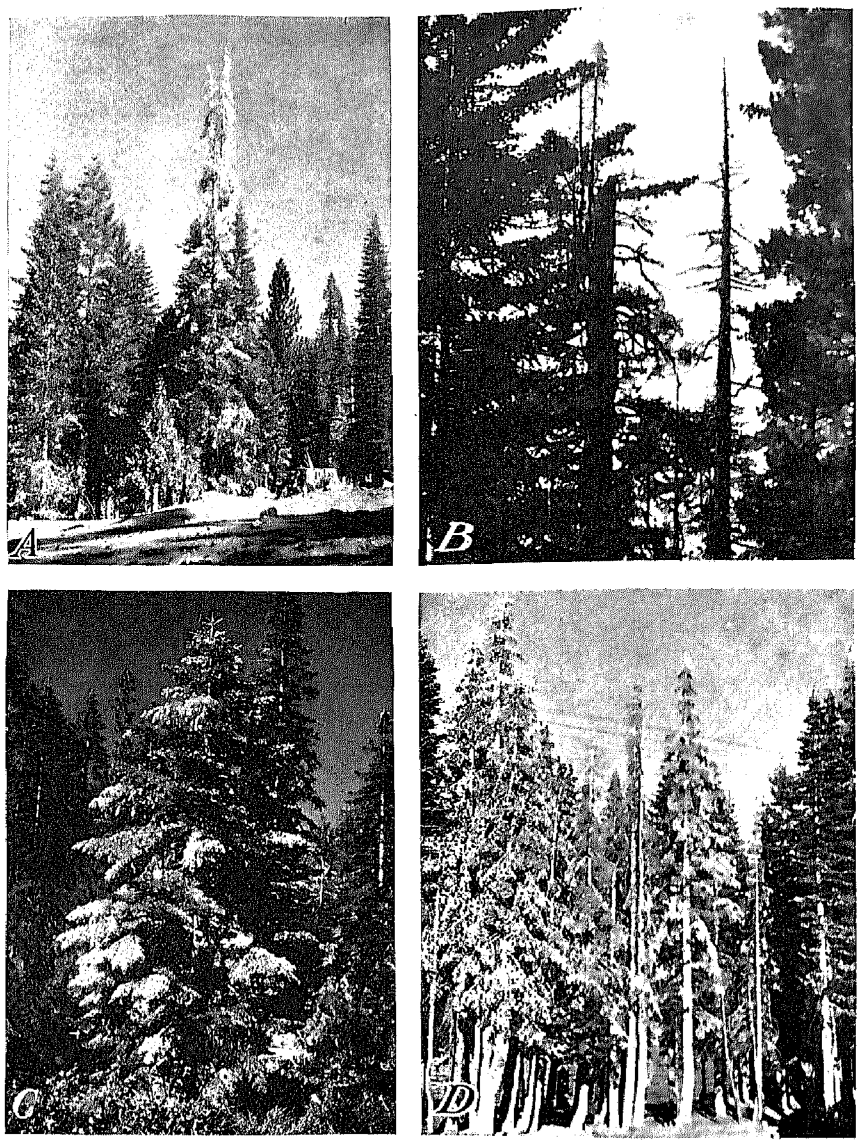
FIGURE 3.—Scars of periodic attacks by *Scolytus ventralis*, healed over and buried in wood: *A*, Drawing of a section of trunk fractured by felling to expose old scars showing preserved beetle work and fungus stain (dates of each attack are indicated); *B*, cross section of same block, showing stained annual rings indicating years of attack; *C*, drawing of tree to show where the section was taken.



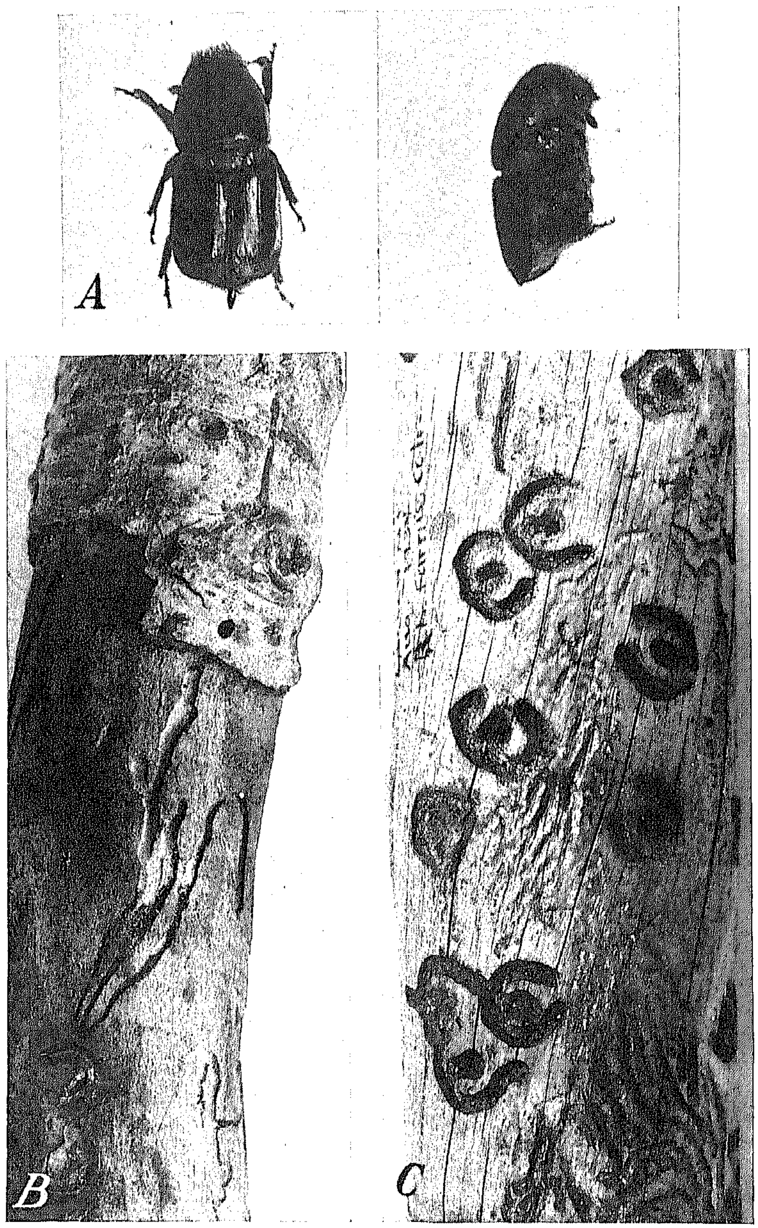
Adult *Scolytus ventralis;* also egg galleries, egg niches, and larval mines cut on sapwood surfaces, representing 40 days of development: *A,* Dorsal and lateral aspects of adult (× 6). *B,* Attack 4 to 6 days old, showing egg gallery and egg niches to the right of the nuptial chamber. *C,* Egg gallery 10 days after attack; this gallery was first constructed to the left, then to the right of the nuptial chamber; the beginning of fungus stain development is shown as darkened areas on each side of the egg gallery. *D,* Galleries 20 days after attack; the oldest eggs have hatched, and young larvae have begun feeding at right angles to the egg gallery. *E,* Galleries 30 days after attack; larvae of many ages are represented by mines of different length; eggs are still being laid. *F,* Galleries 40 days after attack; the egg gallery is nearly completed and the oldest larvae are nearly full grown. (*B-F* are two-thirds natural size.)



Patch killing by *Scolytus ventralis:* *A*, Log of white fir with bark removed to show dead areas of cambium along main bole where prolific broods developed; *B*, old attack partly buried by healing tissue before tree was killed several years later; *C*, old attack completely buried, shown in cross section as a darkened annual ring (scale divisions are one-fourth of an inch).



Types of injury to white fir by *Scolytus ventralis*: *A*, Upper third of crown faded as a result of top girdling along main bole; *B*, "snag" fir tree resulting from successive top killing over a period of years; *C*, fading branches among green ones, the result of partial trunk injury; *D*, group of trees near Lake Tahoe killed during the summer of 1928.



Scolytus subscaber: *A*, Dorsal and lateral aspects of adult (× 6); *B*, section of branch showing larval mines radiating from egg gallery in inner bark; *C*, section of weathered branch showing anchor-shaped egg galleries.

TABLE 1.—*Classification of fir injury and killing*

Type	Portion of tree killed	Frequency	Insect responsible
No. 1	Top only, or a combination of top and patch killing.	Common in all stands, but more frequent in mature virgin stands.	Fir engraver beetle.
No. 2	Patches killed on main trunk, often healing, but weakening vigor of tree.	In all fir stands, but more prevalent in virgin stands.	Do.
No. 3, A	Entire tree killed by 1 season of attack in young and second-growth stands.	Result of beetle epidemics in second-growth stands of pole-size trees and larger.	Do.
No. 3, B	Entire tree killed by 1 season of attack in old mature stands.	Frequent in mature virgin stands	Fir engraver beetle and Sierra fir borer.
No. 3, C	Entire tree killed by successive attacks occurring over a period of years, usually in mature stands.	Common in all white fir stands, especially in mature trees.	Do.

HOST SUSCEPTIBILITY AND RESISTANCE

FIELD OBSERVATIONS

Factors directly responsible for the upbuilding of fir engraver epidemics are not so easily understood as those responsible for western and mountain pine beetle epidemics. Prevailing drought conditions from 1924 to 1927 resulted in widespread losses in ponderosa pine stands from southern Oregon through the Sierra Nevada section, while damage to fir was not so evident. In 1928, following a winter of heavy rains, sporadic outbreaks of the fir engraver beetle, causing death to large groups, often involving as many as 50 trees, were found in scattered localities through the Sierra Nevada section. Damage to fir continued during 1929 but subsided in 1930. Again in 1930, 1931, and 1932, drought caused widespread losses in sugar pine and ponderosa pine, while an increase of fir engraver activity occurred only during 1932 and subsided rapidly in 1933.

The study of natural factors responsible for the success of fir engraver attacks and brood establishment has not gone far enough to warrant conclusions. No correlation was evident in studies on the relation of beetle aggressiveness to site and to growth rate. Trees growing on sites apparently ideal from the standpoint of moisture supply were killed along with those growing under less favorable conditions.

RESISTANCE OF TREES TO CONTROLLED ATTACKS

In a series of experiments under controlled conditions, adult beetles were forced to attack caged portions of the trunks on 11 trees selected as varying in site and growth rate. The height of the cage on the tree, the area of tree surface covered by the cage, and the number of beetles forced to attack were also varied. This method of studying beetle-host relationship, which had proved to be entirely successful with *Dendroctonus brevicomis* Lec., *D. monticolae* Hopk., and *D. frontalis* Zimm., resulted in complete failure of attacks under all conditions tried. The number of attacks attempted was far in excess of the number of beetles admitted to caged areas, but most of them penetrated no farther than the outer part of the inner bark. Repeated attacks by the same adults were repelled each time by conditions found when first entering the bark. Only a few burrows were extended into the beginnings of egg galleries, and none of these was excavated beyond 2 inches. Eggs that were deposited in a few of the longest galleries failed to hatch.

BALSAM AS A REPELLENT

While no positive conclusions were reached in explanation of the failure of attacks in the caging experiments, the fact that balsam is very toxic and repellent to adults of *Scolytus ventralis* offers a partial explanation. A thin film of balsam placed on active adults causes immobility within less than 10 seconds, and later death, while small amounts placed a short distance in front of approaching adults causes hurried reversal of direction. Balsam, produced in living fir bark, is found in blisters, channels, and reservoirs of different sizes along the middle and upper bole, and varies widely in amount and distribution in different trees. Since it has such a profound effect on fir engraver adults, it appears logical to believe that physiological changes within the host, which interfere with balsam production and distribution, may create conditions favorable to the beetle.

ASSOCIATED INSECTS OF SECONDARY IMPORTANCE

Many species of insects are attracted to fir trees after these have been weakened beyond recovery by the fir engraver beetle, and frequently the attacks of certain species precede the fir engraver or may even complete the death of a tree without its assistance. All of these insects attack living tissue, but some are more successful than others in their ability to establish broods. Brief descriptions of the more important species are given. None of the insects included in this group has been studied to the same extent as the fir engraver beetle.

SCOLYTIDAE

Scolytus praeceps Lec., as a rule, attacks the tops under 4 inches in diameter and often the larger branches of trees, after *S. ventralis* has begun an aggressive attack. Sapling fir trees growing under unfavorable conditions are occasionally attacked and killed by it. It resembles *S. ventralis* in general appearance and activity, but is much smaller. Short transverse egg galleries are cut through the cambium, grooving the sapwood and inner bark. The larval habits and mines are similar to those of the fir engraver beetle. Pupation, as a rule, occurs in cells lying immediately below the surface of the sapwood. One generation is produced each year. Adults are in flight from June through September. A fungus-stain organism also found with *S. praeceps* has been isolated by Ernest Wright, of the office of Forest Pathology, Bureau of Plant Industry.[6] Although it causes a stain similar in nature to that associated with *S. ventralis*, it was found to be a different species.

Scolytus subscaber Lec. (pl. 4) in general appearance is similar to the fir engraver beetle, but is somewhat longer and more robust and has very different habits. Until recently[7] it has been confused with

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[6] A paper dealing with the description and characteristics of the stain organisms associated with *Scolytus praeceps* and *S. subscaber* is being prepared for publication by Wright.

[7] BLACKMAN, M. W. See footnote 3.

S. ventralis. *S. subscaber* prefers gnarly or mistletoe-infected branches in which to establish broods, and frequently attacks the main trunk of suppressed trees under 4 inches in diameter. Eggs are packed closely in niches made in the inner bark along the outer rim of an egg gallery, cut in an anchor-shaped pattern, which grooves the sapwood. The egg gallery is much shorter than that of *S. ventralis*, the space occupied by it being seldom more than 14 mm across. Larvae feed individually in mines radiating from the egg gallery. At first the inner bark only is mined out. Later on, as the larvae approach maturity, they mine along the surface of the sapwood. Attacks are made during July and August. A fungus-stain organism found associated with this species is similar to the one found with *S. praeceps*.

Pseudohylesinus grandis Sw. is a grayish-brown beetle slightly smaller than *Scolytus ventralis*. It works along the middle part of the main trunk of dying and dead fir trees and cut logs. Transverse egg galleries, 2 to 4 inches long, groove the sapwood and inner bark surfaces. One generation is completed each year.

Gnathotricus sulcatus (Lec.) is a small, dark reddish-brown, elongate ambrosia beetle, 3 to 3.5 mm long, and is common in the basal trunk of dying and dead trees. It seldom works higher than 10 feet from the ground. Its presence is recognized by fine borings in bark crevices, which are traceable to small round holes penetrating the sapwood to the interior of the trunk. A fungus cultivated near the ends of these galleries serves as food for developing broods.

Platypus wilsoni Sw. is a small, dark reddish-brown, elongate ambrosia beetle, somewhat larger than *Gnathotricus sulcatus*. It is 5 to 5.5 mm long. Each elytron terminates in a point. It works in the lower bole of dying and dead trees in much the same way as *G. sulcatus*, and may frequently extend its activity as high as 40 feet. Shredded white borings in bark crevices indicate its presence. It bores through the sapwood to the interior of the trunk, where it cultivates a fungus which serves as food for developing broods.

Pityophthorus pseudotsugae Sw. is a tiny, elongate, dark reddish-brown to black species. It works in the top of dying or weakened fir and is rarely a primary cause of death to sapling fir. Its tiny egg galleries radiate from a central nuptial chamber. The galleries and the nuptial chamber groove the sapwood and inner bark surfaces. This species is polygamous. One to two generations are produced each year, depending on seasonal temperatures.

CERAMBYCIDAE

Tetropium abietis Fall is of particular importance because of its ability to kill weakened fir trees without the assistance of the fir engraver beetle. Mature trees, suppressed in growth, or weakened by some agency, are attacked and often overcome. Working also in the lower bole of trees severely injured in the top by the fir engraver beetle, it hastens their death. Some trees recover from attacks of *Tetropium*, and scars are found buried in the wood. Although primary at times, *T. abietis* has never shown any tendency to become abnormally abundant or injurious. The larvae feed in the cambium, cutting a winding, sawdust-packed mine which increases in width with larval development. Pupation takes place near the outer bark.

One generation is produced each year. Adults are found during June, July, and August.

Monochamus oregonensis Lec. is a large, robust, black species, often with white markings, and is from 18 to 30 mm long. It works in the top portion of dying and dead fir trees under 10 inches in diameter. The larvae groove the sapwood surface deeply, later entering the wood. Coarse shredded borings of wood are cast to the outside. One generation is produced each year.

Leptostylus nebulosus Horn is a mottled gray beetle, 12 to 18 mm long, and robust. Its broods are produced in the tops of freshly killed fir. One generation is produced each year.

BUPRESTIDAE

Melanophila drummondi (Kby.) is a medium-sized, iridescent black or brown beetle with white spots on the elytra. It is from 9 to 14 mm long. It breeds most frequently in the middle part of the main trunk, but its attacks often extend for the entire length of the bole. Weakened or dying trees and cut logs exposed to full sunlight are most attractive to this insect. It constructs wide, flat, winding larval mines along the cambium layer. Pupation occurs in the outer bark. One generation is produced each year.

INSECT ENEMIES

Parasitic and predacious insect enemies have in some cases been found to destroy as much as 84 percent of the brood of the fir engraver. Most of the enemies follow very closely after the establishment of brood and develop at a similar rate, but others are not active until the brood is nearly mature. Some are voracious feeders, devouring many larvae and pupae; others are ectoparasites. Some are general predators and at times are cannibalistic. The most important species are briefly described.

The ostomid beetle *Temnochila virescens* (Fab.) var. *chlorodia* (Mann.) is a general predator in both adult and larval stages and is associated with many species of bark beetles. The adult is iridescent blue or green, 10 to 15 mm long, and elongate. The eggs are laid in bark crevices. The seasonal development proceeds at about the same rate as that of the fir engraver beetle.

The clerid beetle *Thanasimus lecontei* Wolc. is predacious in the larval and adult stages and is found commonly with other bark beetles besides the fir engraver beetle, especially with *Dendroctonus brevicomis*. The adults are 6 to 8 mm long, black with grayish markings, and very active, resembling ants. The eggs are laid under bark scales or in crevices. The larvae feed on bark beetle broods.

The clerid beetle *Enoclerus sphegeus* Fab. is frequently found with *Scolytus ventralis*, but is more common with *Dendroctonus monticolae* and certain other bark beetles. In both larval and adult stages this species is predacious on bark beetle broods. The adult is 10 to 12 mm long, black with gray markings, and with the ventral part of the abdomen reddish orange.

The clerid beetle *Thanasimus undulatus* Say is found occasionally on trees infested by *Scolytus ventralis*. It is similar in size and appearance to *Thanasimus lecontei*. The abdomen and legs are reddish orange. Adults and larvae are predacious on broods of *S. ventralis*.

Medeterus sp. is a small, gray, long-legged, dolichopodid fly, somewhat smaller than the house fly. It runs sidewise as well as forward and backward. The larvae are found commonly feeding on larvae of *Scolytus ventralis*. This fly also is associated with many other bark beetles.

The braconid *Coeloides scolyti* Cush. is parasitic in the larval stage. The adult is a small wasp with the head and abdomen orange and the thorax black. It has a medium-length ovipositor. This insect is abundant from May to September in the vicinity of trees infested by *Scolytus ventralis*. It deposits its eggs on larvae of *S. ventralis* by inserting the ovipositor through the bark. The larvae are ectoparasites.

The adult of *Coeloides brunneri* Vier. is very similar in appearance to *C. scolyti* and is somewhat larger. It is quite similar in habits to *C. scolyti*, but is not so prevalent.

Cecidostiba thomsoni Cwfd. is a small greenish braconid wasp, with a pointed abdomen and short ovipositor. It is found commonly, but is not as abundant as either of the other two parasites. The larva is an ectoparasite.

The acarid *Pediculoides ventricosus* Newport is a tiny, round, yellowish-white mite, and is an ectoparasite on eggs, larvae, pupae, and adults of *Scolytus ventralis*. It is also found commonly with other bark beetles.

ARTIFICIAL CONTROL MEASURES

Complete control of the fir engraver beetle over large forested areas is impossible. While trees entirely killed may be felled and the broods beneath the bark destroyed, those which are killed in the top or in patches along the bole should not be treated in the same way, because of waste and the possibility that many of the trees will completely recover.

CONTROL OF BROODS IN DEAD TREES

Certain experiments have been tried to determine which method is most practical for use against broods produced in the various situations. Test treatments of broods in dead trees were worked out on the ground after the trees had been cut. These methods included burning, sun-curing, submerging in water, and the application of chemicals to the outer bark. The following conclusions were reached:

(1) Peeling the infested bark off the top half of the log and scorching the rest, as in ordinary methods used in western pine beetle control, resulted in 100-percent mortality.

(2) Sun-curing is successful in bark up to 20 mm thick when air temperatures are 80° F. or above. Logs must be exposed to full sunlight for at least 6 hours daily while lying in a north and south direction, and turned one-third over every 5 days until all surfaces have been exposed.

(3) Submergence of brood logs in water for 6 weeks resulted in 99-percent mortality. Control by submergence is feasible near lake shores or mill ponds only when brood logs can be left in the water for a considerable period.

(4) Application of dusts and oils was ineffective. Those tested were sodium fluosilicate dust, creosote emulsion, petroleum oils, and paradichlorobenzine dissolved in linseed oil.

DISCUSSION

Unless broods in top-killed trees or in injured areas of cambium are destroyed, the effect of brood control in dead trees is largely nullified. Because top-killed trees and those partly injured often completely recover, there remains a question of the desirability of felling them and destroying the broods. The dead tops do considerably increase the fire hazards, according to foresters.

Although fading foliage indicates the presence of an infestation in top-killed trees, it does not always do so in trees with patch killing, unless the patch killing girdles the limbs. The broods in killed patches are frequently very numerous and, unless they can be located and destroyed, may be the source of future attacks and epidemics.

Because of the difficulties involved, artificial control is of little value on large timbered areas. In the writer's opinion, control measures may be practiced with success on private property or on intensively used recreation areas if the following procedure is observed:

(1) Fell and burn all trees suspected of fir engraver injury, from trees killed and top killed to those with dead branches scattered throughout the crown.

(2) Fell all trees weakened by suppression or other causes.

(3) Thin the remainder of the stand, allowing only the more vigorous trees to remain.

(4) Make sure that no green logs lying on the ground as a result of control work are left for breeding places of the beetle.

The practice of the control methods thus outlined is a joint problem for the forest pathologist and the entomologist. Until such methods (which are applicable only to the intensively used fir forest) are employed, control of the fir engraver beetle must be left to natural factors.

SUMMARY

The fir engraver beetle (*Scolytus ventralis* Lec.) is a major cause of damage and death to forests of fir in the West. From 1928 to 1930, and again in 1932, sporadic outbreaks of local nature appeared in California and Oregon, doing considerable damage to second-growth forests.

White fir, lowland white fir, and California red fir are the preferred host trees, but occasional damage is done to Douglas fir, mountain hemlock, alpine fir, and Engelmann spruce. The range of *Scolytus ventralis* is known to extend from British Columbia to New Mexico and east to the Rocky Mountains.

The beetle kills or damages its host by cutting transverse egg galleries along the cambium layer, resulting in girdling of the trunk or in patches of dead cambium. The larvae mine separate channels at right angles to the egg gallery along the cambium layer, causing further damage. A fungus stain introduced by the beetle and found with every attack is apparently an important factor in insuring the success of the beetle, as it apparently assists in overcoming the resistance of the host.

The length of the life cycle depends on prevailing temperatures at the altitude and latitude of the host trees. In the central Sierra Nevada one generation is produced each year at elevations between 4,500 and 6,000 feet, one generation every 2 years at elevations above 6,000 feet on north exposures, and one and a partial second generation

at elevations between 3,500 and 4,500 feet on south exposures. The broods hibernate only in the larval stage. The egg stage and the pupal stage are completed within 10 to 14 days. Adults are in flight from June into September, the maximum number being found during July and August.

Under normal conditions *Scolytus ventralis* breeds in old or weakened trees, killing the tops or patches of cambium along the bole. New leaders which have grown out to replace the old tops are often attacked and killed. Top killing often continues on the same trees for several years, each season of attack resulting in additional crown injury, until the tree is weakened beyond recovery. In vigorous trees injured areas of cambium ordinarily heal over and the scars are buried in the wood along the annual ring of the year of attack.

During the sporadic outbreaks entire trees and groups of trees are killed in a single season. At such times trees of all ages (from poles to mature timber) may be attacked without apparent choice as to site or growth rate.

Trees weakened by the fir engraver beetle are often readily attacked and killed by several species of associated secondary insects. The cerambycid *Tetropium abietis* is the most important in this group.

Scolytus ventralis is held in check naturally by several species of parasitic and predacious insect enemies whose numbers increase with the numerical increase of the beetle.

Artificial control measures are limited because of the wide variation in kill and brood establishment. Unless the broods in top-killed trees or in partially injured boles can also be destroyed, the benefit from destroying broods in trees killed is largely nullified. The most practical means of control is by felling, peeling the bark, and burning.