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BIOLOGY AND CONTROL OF *MONOCHAMUS* AND *TETROPIUM*, THE ECONOMIC WOOD BORERS OF ALBERTA (COLEOPTERA:CERAMBYCIDAE)

by

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TABLE OF CONTENTS

Page

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by

A. G. Raske*

INTRODUCTION

Over twenty species of long-horned wood borers of the family Cerambycidae occur in Alberta and a similar number of species of metallic wood borers of the family Buprestidae. Other common wood boring insects in conifer logs are several species of wood wasps of the family Siridae and one species of the beetle family Melandryidae. Only two species, *Monochamus scutellatus* (Say) and *Tetropium parvulum* Casey, both Cerambycidae, cause economic damage in Alberta. This damage consists of degrade of lumber caused by 1) "worm holes" made by the immature forms, called grubs, and by 2) stain fungi introduced into the wood by the wood borer larvae.

The white-spotted Sawyer beetle, *M. scutellatus*, is generally of greater economic importance than *T. parvulum*. Two other species of *Monochamus* occur in Alberta: *M. maculosis* Hald., and *M. notatus* (Drury) (Hopping, 1921), but both are relatively rare. *Tetropium parvulum* is at times extremely abundant in large-diameter spruce logs.

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Prompt utilization of logs as currently practiced by most established mills prevents practically all wood borer damage in Alberta. But in the last few years some Alberta mills have had to close down and other mills lost thousands of dollars due to degrade caused by wood borer damage. In some cases poles for export have been rejected because of extensive wood borer holes.

This report summarizes current knowledge on the biologies of _Monochamus_ and _Tetropium_ spp. and presents guidelines for their detection and control.

MONOCHAMUS

The common _Monochamus scutellatus_ consists of two sub-species, _M. scutellatus scutellatus_ and _M. scutellatus oregonensis_ LeConte, which are difficult to distinguish (Raske, 1972a). _M.s. scutellatus_ occurs from Newfoundland southward to North Carolina and westward to central Alberta and British Columbia, and then north westward into Alaska (Dillon and Dillon, 1971). Its distribution in Alberta tends to follow that of jack pine (_Pinus banksiana_ Lamb.) and also includes the mountain areas south to about Jasper National Park. _M.s. oregonensis_ is found in western North America from the Rocky Mountains to the Pacific coast and northward into British Columbia and Alaska (Dillon and Dillon, 1941). In Alberta it occurs in the mountains and along the foothills north into Banff National Park.

LIFE HISTORY

Because the life history and habits of the two Monochamus subspecies are very similar they are combined in this report, and unless specified the information has been confirmed for both the eastern and the western subspecies.

The beetles emerge from infested logs generally from about June 15 to mid-August with peak emergence between June 20 and July 10 (Raske, unpublished data), although some individuals may emerge in early May. The adults feed for 3 to 7 days on the tender bark of pine or spruce twigs and sometimes on the needles (Linsley, 1961; Wilson, 1962). Feeding on the bark often causes the twig beyond the wound to die, resulting in a condition called flagging. After feeding the female beetles find recently cut logs, recently dead trees, or dying trees for egg laying because only such logs or trees are attractive to them (Craighead, 1923, 1950; Graham, 1957; Keen, 1952; Wilson, 1962). No attacks occur on trees dead for more than 9 months (Parmelee, 1941).

Males and females meet on suitable host trees and mating takes place on the boles on warm sunny days (Rose, 1957). Both sexes mate repeatedly in their life time. Mated females chew elliptical egg niches into the bark of the tree (Fig. 1), which are almost always at right angles to the grain. The length of egg niche varies according to bark thickness, from 1/8 inch in thin bark to 1/4 inch in thick bark. Females of M. scutellatus lay only one egg per egg niche, which is wedged into the phloem below the egg niche (Fig. 2). Not all egg niches are used for oviposition. Rose (1957) found 30% of the egg niches utilized in field populations, while the percentage used for oviposition for 34 individually caged females from Alberta varied from 27% to 50%, and averaged 35.8%. Most females laid 15-20 eggs during their life time, but one female layed 43 eggs and had 16 mature eggs plus many undeveloped eggs remaining in her ovaries (Raske, unpublished data).

Adult females in the laboratory lived about 40 days and males about 30 days; one female stayed alive for 82 days. Egg laying ceased after the first three weeks (except for an occasional egg). The eggs hatched after 10-17 days (average 12 days) under laboratory conditions which is similar to what Rose (1957) found in the field.

The newly hatched larvae are about 3/16 inch long. They tunnel into the phloem and reach the cambium by about the third day of life; there they continue to feed on the phloem till mid- to late-August and begin scoring the wood surface after 3 weeks of feeding (Rose, 1957). By early September most have developed into the third instar and are about one inch long. They then bore into the wood, reaching a depth of two to three inches in 2 weeks. Larvae from eggs, laid early in the season in exposed logs, developed faster and bored into the wood in early August and reached their full size of about 2 inches by late August. While excavating in the wood, the larvae often return to the surface to feed on the phloem. As the larvae grow the tunnel is continually enlarged. By October the larval tunnel has reached its maximum depth and the larvae then turn and mine more or less parallel to the grain, either going up or down the stem.

Smaller larvae from eggs laid late in the season will still tunnel into the wood to approximate maximum depth by late September. Several larvae that did not bore into the wood did not survive the winter.

Little frass is extruded by the larvae during the first season, rather it is tightly packed into the larval mines under the bark. Since most of the frass is extruded during the second season, it has given rise to the false impression that logs are attacked only during the second season.

In Alberta both the one-year and the two-year life cycles have been recorded. The one-year cycle predominated in the Lac La Biche and Grande Prairie regions (*M.s. scutellatus*), while the two-year cycle predominated in the southern Foothills (*M.s. oregonensis*). Three- and four-year life cycles were recorded from logs in deep shade. Logs receiving much sunshine may be mined extensively the first season if that season is warm and dry, and under these conditions large amounts of frass are extruded from the log in the first year.

The next spring, after egg-laying, the larvae continue their feeding and mining, and it is generally at this time that the frass, which is composed of excreta and excelsior-like wood particles, is extruded from under the bark. During this period the larvae "scar" the surface of the sapwood (Fig. 8a), rather deeply and irregularly.

Pupal cells are constructed close to the surface of the wood (Fig. 9) in late spring, and consist of an enlarged area of the larval mine sealed off from the rest of the larval mine with a dense fibrous plug. Larvae which are not mature by the following spring, continue to mine throughout the summer, producing fairly large amounts of frass, and these usually pupate the next spring completing their life cycle in two years.

Pupae are formed from early May to late July, with a peak in late May, and lasts from 8 to 14 days. The adults remain in the pupal cell for about one week while the insect body hardens. They then emerge from the logs by chewing a circular exit hole (Fig. 8d).

DESCRIPTION OF LIFE STAGES

The egg, larva, and pupa of the various species of *Monochamus* are extremely difficult to separate, therefore the following descriptions are applicable for all *Monochamus* species.

Egg

The egg is creamy white in color, elongate and often slightly curved, with one end being slightly wider than the other (Fig. 2). It averages about 3.5 mm in length and 1 mm in diameter.

Larva

Upon hatching the larva is slightly larger than the egg, grayish in color and slightly flattened. It grows rapidly to a maximum length of about 2 inches and 1/4-inch in diameter (Fig. 3). The head is yellow to brown and is mostly buried in a large swollen prothorax which is light yellow on the top. The sides of the head are almost parallel (to each other) (Fig. 4) rather than decidedly rounded as in practically all other Alberta wood borers. The larva is completely legless.

Pupa

The pupa resembles a partially formed adult (Fig. 5), having reduced wings while its legs, mouth parts, and antennae are clearly distinguishable. Its body is 5/8 to 1 inch long, creamy white when first formed, but the eyes, mandibles, antennae, legs and edges of abdominal segments darken as it matures. The long coiled antennae are characteristic of Monochamus.

Adult

The adult is a striking large black beetle with very long antennae (Fig. 6,7). The body is about one inch long and the antennae of a large male may be over two inches long; the antennae of the female are only slightly longer than the body and are distinctly ringed with white. The wing covers (elytra) of males are shiny black and occasionally spotted with patches of white hair. The elytra of females are usually spotted with white but may be black like those of the males. Each sex has a spine on the side of the prothorax and a small white spot at the base of the wings which gives it the name 'white-spotted sawyer beetle'.

DAMAGE

Damage caused by Monochamus is twofold: 1) tunnels in the wood cause degrade of lumber and therefore monetary loss and, 2) larval holes provide an entrance for stain and decay fungi, which causes discoloration of the wood and enhances wood rots (Prebble and Gardiner, 1958).

Loss of volume in pulp wood logs is insignificant (Prentice and Campbell, 1959; Wilson, 1961) but degrade of lumber caused by deep tunnels and discoloration can be considerable (Becker and Abbott, 1960; Prebble and Gardiner, 1958). Studies showed that monetary losses can be as great as

30% of the net price for the mill operator (Safranyik and Raske, 1971).

The entrance hole is found within the "scored" area on the log surface and is distinctly elliptical in shape (Fig. 8b). Other insects chew circular entrance holes or holes whose sides are parallel. The larval mines of Monochamus are cleared of debris and are empty except for the dense fibrous plug of the pupal cell. Many other wood boring insects firmly plug their larval mines with granular frass.

The larvae penetrate the log 4 to 5 inches on the average and occasionally up to 8 inches by the fall of the first summer season (Gardiner, 1957; Ross, 1966). At times larvae will increase their penetration during the second summer by meandering. This habit of boring deep into the wood makes Monochamus the most economically important wood borer in Alberta.

GENERAL

The larvae develop successfully only in weakened or recently dead coniferous trees, or recently cut logs. All members of the Pinaceae in Alberta are attacked, but the pines and the white spruces are the preferred hosts. Generally eggs are deposited on all logs with diameters greater than 3 inches. When both pine and spruce logs, cut the same date, were available to the adult for oviposition, higher larval populations were found in spruce near Whitecourt and Rocky Mountain House, while higher larval populations were found in pine near Wandering River, Ricinus, Blairmore and at the Kananaskis Forest Experiment Station.

Adults are active only on sunny and warm days, when they can be seen walking over the logs, but females prefer shade for oviposition. Most eggs are laid on the sides of logs, slightly below the mid-line (Rose, 1957). The least number of eggs are laid on the bottom of the log and an intermediate number are laid on the top. The ratio of eggs laid is about 10:3:1 for sides, top and bottom respectively, (Raske, unpublished data). In standing trees larvae are evenly distributed around the circumference and tend to increase in numbers with tree height (Belyea, 1952).

Adults are strong fliers and observations indicate that M. scutellatus can travel at least 6 miles. Ross (1966) concluded from laboratory studies that M. maculosis could travel up to 60 miles within a 5 week period. Because the beetles have the ability to disperse over large areas, they can congregate in large numbers in logging areas or in recent burnt areas.

Generally, only a small percentage of the eggs that are laid reach the adult stage. Many different organisms cause mortality of larvae and pupae. Insect predators have rarely been recorded, but some mortality occurs when barkbeetle predators have access to cerambycid galleries and when the wood borer larvae are small. Parasites and diseases seem to be most prominent in the late larval and pupal stages (Soper and Olson, 1963). Woodpeckers may also prey on mature wood borer larvae (Soloman, 1969; Wickman, 1965) and Ross (1966) felt that the scarcity of wood borer emergence was due to heavy winter predation of woodpeckers.

Several species of parasitic wasps were reared and a few species of parasitic flies are known, but all parasites are not common, only occasionally are they abundant enough to kill a large proportion of wood borer larvae (Morgan, 1948; Soper and Olson, 1963).

Often large numbers of wood borer larvae were found dead in extended larval mines or in pupal cells, apparently overcome by disease. So far, attempts to identify a primary entomophagus disease organism from these dead larvae have failed. Soper and Olson (1963) isolated a fungus, *Beauvaria bassiana*, from *Monochamus* larvae and found that this disease killed up to 36% of the *Monochamus* larvae in the samples. Most of the dead larvae found in Alberta had similar symptoms to those described by Soper and Olson (1963) for *Monochamus* larvae infected with *Beauvaria bassiana* strain "A".

Woodborer larvae are consistently associated with blue stain and brown stain fungi. The precise relationship is not known, but the stain fungi follow the larval mines into the log and stain the wood surrounding the mine. The stain associated with the mines may cause as much degrade to the lumber as the larval mines.

HOW TO RECOGNIZE *MONOCHAMUS**

Monochamus and its damage can be readily separated from other wood borers as follows:

1) Adult - A large slender, elongate beetle, black or mottled with white, and usually about an inch in length, with antennae longer than the body. (Fig. 6 and 7).

*Insects found under the bark or in the wood may be sent for identification to: Northern Forest Research Centre, Canadian Forestry Service, 5320-122 Street, Edmonton, Alberta. Larvae should be placed in a container with a liquid containing some alcohol and packaged well.

2) Larva - A completely legless grub, sides of brown head capsule are only slightly arched (Fig. 4). A 10X hand lens should be used to check these characteristics.

3) Larval entrance holes into log - elliptical and approximately the size of a pencil (Fig. 8b).

4) Frass (droppings plus wood shavings) - excelsior-like, never granular; packed loosely and, often extruded through the bark from the interior of the log (Fig. 8c).

5) Damage - log surface scored, up to 1/4 inch deep and irregularly (Fig. 8b).

TETROPIUM

The wood borer, Tetropium parvulum Casey, is the only common Tetropium species in Alberta. In Alberta, white and Engelmann spruce (Picea glauca and P. engelmannii Parry) are its primary hosts, while pines are apparently not attacked. This borer is found throughout Canada and from Central United States to Alaska (Raske, 1972b; Linsley, 1962). This species has often been confused with Tetropium cinnamopterum Kirby, which is more common in eastern Canada than T. parvulum and most of the biological information published refers to T. cinnamopterum (Belyea, 1952; Craighead, 1923; Gardner, 1957) and two papers (Roff, 1967; Ross and Vanderwal, 1969) record biological notes of T. parvulum under the name of T. cinnamopterum.

LIFE HISTORY

In Alberta, only a one-year life cycle was recorded. Adults of *T. parvulum* emerged from late May to July, with a peak emergence in early June. They will not reinfest the tree from which they have emerged, but immediately fly to a recently cut log or dying tree where mating occurs. Although adults are active during the day they are not readily seen because they hide beneath bark scales and run quickly into an adjacent "hiding" place. The female oviposits into cracks and crevices of the bark and under bark scales, and since she darts from one hiding place to the next, many eggs are laid in close proximity to one another. The average number of eggs laid by a female is not known, but up to 155 eggs for one female has been recorded (Ross and Vanderwal, 1969). Because adults emerge throughout the summer, eggs are also deposited throughout the summer season.

After hatching the larva mines the phloem, hardly scoring the wood. The resultant feeding area is an elongated patch (Fig. 13) tightly packed with fine excelsior-like frass. Near the margin of the patch the larva enters the wood and forms an "L"-shaped tunnel (Fig. 14), the distal end of which is slightly enlarged to form a pupal cell (Fig. 14). Some larvae enter the wood near the first of July, or about 6 weeks after hatching. Larvae from eggs laid later in the season, enter the wood as they mature, and all are full grown by September, have entered the tunnels and have tightly plugged their entrance holes at the surface of the log. Another plug is then constructed to seal off the pupal cell. The larvae overwinter in the pupal cell and transform into pupae (Fig. 11) the following spring or early summer.

The pupal stage lasts about 10 days under laboratory conditions and then they transform into adults, which remain in the pupal cell for about a week while the insect body hardens. The adults then emerge via the larval entrance hole, by removing the two plugs from the larval tunnel, and chew their way out through the bark.

DESCRIPTION OF LIFE STAGES

Tetropium larvae are difficult to recognize, and identification requires at least a 10X hand lens and a little experience.

Larva

A mature larva is 3/4 to 1 inch long (Fig. 10). Its yellow brown head is not deeply embedded in the "swollen" prothorax like *Monochamus*. Like many other wood borers the sides of the head are distinctly arched but unlike many other wood borers *Tetropium* larvae have fine yellow hairs on the sides of the head. These hairs are barely visible with 10X hand lens. The larvae have a pair of tiny legs on each of the first three segments behind the head. All the distinguishing characteristics mentioned so far are shared by all members of the group of wood borers to which *Tetropium parvulum* belongs (Aseminae). But *T. parvulum* can be distinguished from others of this group by the size and spacing of two peg-like structures on the top of the last abdominal segment (Fig. 12). This character can be seen with a 10X hand lens and is not shared with any known woodboring species.

Pupa

The pupae resemble a partially formed adult (Fig. 11). Its wing covers (elytra) are greatly reduced, but the legs, mouth parts and antennae are clearly distinguishable. The pupae is about 1/2 inch long, creamy white in color when first formed, and the eyes, mandibles, antennae, legs and edges of the abdominal segments darken as it matures.

Adult

The adult beetle is dull brown, somewhat flattened, and about 1/2 inch long (Fig. 17). Its antennae extend only to its hind legs. Its uniform brown color, length of antennae and constriction between the elytra and prothorax distinguish it from other kinds of beetles found in fresh logs.

DAMAGE

Like Monochamus the damage by Tetropium is twofold, 1) larval holes in the lumber cause degrade and 2) the larval tunnels into the wood enhance the penetration of stain and rot fungi.

This wood borer penetrates the logs 1-1/2 inches on the average and occasionally up to 2 to 3 inches. The larvae do not meander in the wood but make an "L"-shaped gallery (Fig. 14). It usually is not an economic problem because most larval mines are eliminated with the slabs and edgings. However, the larvae are at times so abundant that the small percentages of larval mines not eliminated with slabs and edgings still cause degrade in a large portion of the lumber. Ten larval holes per running foot is common in dimension lumber sawn from infested logs.

GENERAL

Larvae develop successfully only in weakened or recently dead spruce trees or in recently cut spruce logs. The adults show a very definite preference to large-diameter logs. Often, logs 18-24 inches in diameter, were very heavily attacked while adjacent 12 inch logs were virtually unattacked. Small-diameter logs are attacked only when large diameter logs are not available.

Mortality of larvae and pupae is usually high because predators, parasitic wasps, and a "suspect disease" are very common. Insect predators appear to be unimportant but woodpeckers at times kill a large number of larvae and pupae, because of the shallow boring-habit (Ross and Geistlinger, 1968). Woodpeckers killed an estimated 80% of the larvae at the base of a spruce tree but higher up the stem among the branches, practically no woodpecker activity was evident even though Tetropum larvae were abundant.

A black parasitic wasp (Rhimphatona alaskensis (Ashmead) (Ichneumonidae)) has often been reared from Tetropium larvae (Fig. 16). In addition, at several localities, 50% or more of the larvae were found dead in the pupal cells covered by a white fungus (Fig. 15). So far attempts to find a primary entomophagus disease organism from these dead larvae have failed. Symptoms of death are very similar to those caused by Beauvaria bassiana, strain A, in Monochamus larvae as described by Soper and Olson (1963).

Heat is another factor that apparently kills large numbers of Tetropium larvae. It was repeatedly observed when, during the first of a series of hot days, the larvae in the top of unshaded logs (such as surface logs of a deck), were found dead and were lacking any symptoms of disease; in such instances the inner bark was decidedly warm to the touch. Along the sides of the same logs where the inner bark was cooler, no dead larvae were found.

Tetropium larvae are consistently associated with wood staining fungi, which stain wood areas surrounding the larval tunnels in logs. Thus the larvae seem to assist the fungi in penetrating the log.

HOW TO RECOGNIZE *TETROPIUM*

Larvae, adults, and damage caused by *Tetropium* are not readily identified by a non-specialist; larvae are probably the easiest stage to identify using Figs. 10 and 12.

1) Adult (Fig. 17) - A slender uniformly brown beetle with antennae extending to hind legs and with a constriction between prothorax and wing base.
2) Entrance hole into log elliptical, longest diameter 1/8 - 3/16 inch and plugged in late summer and fall.
3) Frass (excreta plus wood shavings) - fine shreds of wood tightly packed in irregular "patch"-shaped larval mines (Fig. 13).
4) Damage - wood surface slightly scored and only adjacent to entrance hole.

CONTROL OF WOOD-BORING INSECTS

SILVICULTURAL CONTROL

Prompt Utilization

The best control of wood-boring insects is achieved by prompt utilization of logs, which generally is the current practice of the logging industry.

Cutting schedules should be timed so that logs cut between fall and June are processed before the following September. Unsawn logs should not be left for a full summer season. In general, logs left in the bush are more heavily attacked than those piled at a mill, therefore logs should be hauled out and decked at the mill site if possible.

It is important to realize that logs are attacked by wood-boring insects only during the first summer season; no additional eggs are laid on logs during the second, third, etc. seasons. Damage may increase slightly in the second year only because of the larger size of the wood borer larvae; but not because there are more of them. However, degrade caused by stain and rot fungi increases after the first summer season (Kimmey, 1955).

Time of Year When Logs Are Cut

Studies showed that the time of the year when logs are cut influences how heavily the logs are infested by Monochamus (Tothill, 1924) and by *Tetropium* (Vanderwal and Ross, 1968). Logs cut in fall and early winter tend to be unattractive to adults and are therefore lightly infested. Logs cut in May and early June are very attractive and tend to be heavily infested, while logs cut in February, March, and April are intermediate in degree of infestation.

If feasible, it would be advantageous to concentrate felling operations between September and January. If logs are cut after January every effort should be made to have these logs processed before the following September.

If some logs have to be left in the bush due to early spring break-up or some other reasons, then fall-cut logs should be left in the bush and not spring-cut logs.

In summary, spring cut logs are very attractive and should be promptly processed, while fall cut logs are less attractive and have a good chance of escaping insect attack if left for the summer season.

Decking Logs

Studies showed that limbed logs left scattered on the forest floor are infested twice as heavily as surface logs of cold deck piles (Raske, unpublished data). If the logs are decked so that little light penetrates the interior of the deck, very few eggs will be laid below the surface log layer (Wilson, 1960). In contrast, all logs left scattered on the forest floor tend to be infested.

NON-CHEMICAL DIRECT CONTROL

Several methods can be used to reduce or eliminate wood boring insects from logs. All of these are preventive measures and generally do not kill the insects once they are established in the logs.

Ponding

Storage of logs in ponds practically eliminates all wood boring insects (Gardiner, 1962; Dobie, 1965; Smith, 1965). Logs need only be ponded the first summer season. A few attacks might occur in the exposed dry top of the log but these larvae generally do not survive (Chesley et al., 1956).

Sprinkling

The use of water sprinkled onto decked logs will reduce and can prevent all wood borer damage (Carpenter and Toole, 1963; Dobie, 1965; Mason et al., 1963; Roff and Dobie, 1968). This is a low cost effective method if sufficient water is nearby. If this method is used in a mill yard where heavy machinery is in use, then drainage of the excess water is an important consideration.

Either fixed-head or rotary-head sprinklers may be used as long as good coverage of the deck is achieved and the logs are kept wet while the sprinklers are in operation. Good control has been achieved by sprinkling water for 15-20 minutes of each hour, day and night at a cost of about 3 to 7 cents per M bd ft (Roff and Dobie, 1968). Both fixed-head and rotary-head sprinklers may be used, but care must be taken that all parts of the deck are covered with water. Roff and Dobie (1968) give an example of the equipment needed for sprinkling logs.

Shading Logs

Since the adults are sun-loving insects, logs kept in continuous shade will have reduced insect attack. This has been accomplished by covering the decks with logging slash (Wilson, 1960). Care should be taken that moisture is able to escape from the deck and allow the logs to dry, otherwise stain fungi will discolor much of the sapwood in a very short time causing more damage than the wood-boring insects.

Peeling

The removal of all bark from the logs will prevent all wood borer attacks (Smith, 1965; Wilson, 1962). This is generally not economical and results in severe checking unless the logs are processed in a very short period of time, or are ponded after debarking.

CHEMICAL CONTROL

Preventive Control

Chemical sprays have given consistently good control of wood-boring insects. Apparently the chemicals prevent the female from laying eggs. Two chemicals have been used successfully as preventive sprays 1) BHC (benzene hexa-chloride) (Gardiner, 1970; Becker, 1955, 1961; Becker and Abbott, 1966) and 2) Lindane (an isomer of BHC) (Ross and Downton, 1966; Ross and Geistlinger, 1968; Becker et al., 1956). Many other chemicals have been tried with various degrees of success (Becker, 1952, 1964a; Fystro and Bakke, 1962; Simpson, 1951; White, 1967; Durr, 1954; Tooke, 1948; Richmond, 1967, 1969; Keino, 1969; Allen and Rudinsky, 1959). In addition many chemicals have been tried for the control of bark beetles (Lyon, 1965) which may also kill wood borer larvae still within phloem tissue. Some insecticides have given good control when applied to floating log booms (Hedlin and Woods, 1970).

Sprays can be applied to standing trees, logs, or log decks, and should be applied before egg-laying has begun (about June 1) or even before cutting in fall (Becker, 1964b). One treatment with Lindane or BHC will protect the logs all season and the logs will be too dry to be suitable for egg-laying the following season. Trees cut in June or July should be sprayed within a day or two (Wilson, 1961).

Logs should be sprayed till the bark is dripping wet, and if possible, they should be turned over and the bottoms sprayed as well. Log decks should be liberally sprayed to cover the tops, sides, and ends of the logs. When spraying the ends of log decks care should be taken to penetrate the deck with insecticide.

Although a few logs may be sprayed with a hand-operated sprayer, motor-powered sprayers are needed for commercial treatment. According to Becker (1961), pumps that can deliver 3 gallons per minute at 250 pounds pressure and equipped with 15-30 gallons of spray are satisfactory for smaller treatments, while larger pumps with 200-500 gallon tanks are needed for larger operations. Spray pumps should be adjustable and equipped with spray disks of different interchangeable sizes so enough spray can be delivered per minute to wet the logs to the point of run-off in approximately the time it takes to obtain complete spray coverage. The spray nozzle should be adjustable to obtain a wide or narrow spray pattern. Recently, attempts have been made to spray log decks from an helicopter (Harris *et al.*, 1968) but good control was not achieved.

1) BHC

A BHC emulsifiable liquid concentrate is commercially available, and can be diluted with water to form the final emulsion. The insecticide can also be mixed with kerosine or fuel oil (Gardiner, 1970), but this mixture is costly and difficult to handle. BHC concentrates are sold in different concentrations of the active part which is called the gamma isomer. The percent concentration is printed on the label. Becker (1958) gives the following formulas for mixing the various concentrates with water to make the finished spray* at 0.4% gamma isomer by volume:

Gamma Isomer Content of Concentrate	For 10 gallons (U.S.) of spray	For 100 gallons (U.S.) of spray
10%	3 1/3 pints	4 gallons (U.S.) 1 pint
11.8%	2 4/5 pints	3 gallons (U.S.) 2 quarts
15%	2 1/5 pints	2 gallons (U.S.) 3 quarts
20%	1 2/5 pints	2 gallons (U.S.) 1/2 pints

About 12 gallons should be used per M.B.F. of lumber, or 80 gallons for a deck 25 ft long, 6 ft high, composed of 12 ft logs. Cost of materials is approximately $1.10 to $1.30 per M.B.F. (1960 prices, excluding cost of spray equipment) and it will take 0.1 to 0.2 man-hours per M.B.F. to treat decks of logs (Becker and Abbott, 1966).

2) <u>Lindane</u>

Lindane emulsifiable concentrate should be diluted in water to a 1% concentration of the gamma isomer (Ross and Geistlinger, 1968;

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*Mix just before spraying.

Ross and Downton, 1966; Becker et al., 1956). The amount of spray needed is the same as for BHC.

Cost figures are not available but should be slightly higher than those for BHC.

It is of interest to note that Lindane killed a high percentage of wood borer larvae established under the bark, and prevented them from penetrating the log (Ross and Downton, 1966). Therefore, this chemical could be applied later than BHC and still give effective control.

Like all insecticides, BHC and Lindane are poisonous and all manufacturers' instructions and warnings should be strictly observed. Avoid inhaling the spray mist, and contact with skin and eyes. Wear rubber gloves, chemical cartridge type respirator and, if possible, a rubber coat or rain suit. Do not use chemicals where it might drift into food, food crops, forage crops, lakes, streams, or contact domestic animals. Although no damage or difficulty is known to date, until further information is available, it is not recommended that sprayed lumber be used for special purposes, such as food containers, or the sawdust used around food crops or around domestic animals.

Treatment of Infested Logs

Chemical treatment of infested logs is practical only if applied during the first summer season before the wood borers have begun to bore into the logs.

If a sample of logs indicates that many young larvae are present or if it is suspected that many eggs have been laid in the logs, then chemical treatment could be a reasonable course of action. Safranyik and Raske (1970) have devised a sequential sampling system for classifying the severity of damage by Monochamus larvae in decked and scattered logs of lodgepole pine that relates damage class to expected monetary loss. This system can be used to determine the feasibility of control treatment.

Treatment of infested logs with PDB (para dichlobenzene, commonly called moth balls) has given excellent control of wood boring insects in small experimental decks (Raske, 1971c). The chemical is dissolved in trichlorv ethylene*, 1 gm of PDB per 1 ml of solvent or 2.2 lb of chemical per quart of solvent, poured onto the deck and covered with plastic sheeting. The chemical is poured evenly over the top along the mid line of the deck at a rate of 4 lb of chemical per 1000 cu ft of volume (volume equals wood plus air space under the covering) or 1/2 gal of dissolved chemical for every 1000 cu ft of volume. The deck should remain covered for at least 2 days, but no more than 7 days.

Even though the chemical is one of the safest insecticides the usual precautions should be followed. Decks treated should be well posted with warning signs.

Estimated cost of insecticide plus plastic sheeting (6-mil thickness) is 10¢ to 20¢ per M.B.F. If care is taken to prevent snagging and tearing of the plastic sheeting, so that it can be re-used,

*Available under the trade name of "New Tri" from Dow Chemical of Canada.

the cost of treatment can be further reduced. The number of man-hours required for treatment is not known, but should be small. One disadvantage of this method is that treatment must be done on days with little wind, since high winds would easily tear the plastic or blow it off completely.

FIRE-KILLED TIMBER

Lumber from fire-killed timber is subject to degrade by three different agents, insects, checking, and rot and stain fungi. To minimize these losses it is important that salvaging operations be started and completed as soon as possible. However, all timber that cannot be processed by the end of the first summer season is not lost. Since fire alone consumes very little sound wood (Beal *et al*., 1935), subsequent losses are caused by insect damage, checking, and rot and stain fungi. Degrade of lumber due to insect damage begins during the first summer season after the fire, while losses due to checking usually during the second season, (in severely burned trees) (Richmond and LeJeune, 1945), and losses due to rot and stain fungi usually after the second or third season (Basham, 1957).

Fire-killed conifers are highly susceptible to wood boring beetles, which are attracted to the burned-over area in surprisingly large numbers. Because of the large numbers of *Monochamus* and *Tetropium* adults attracted to burned areas and the speed with which they can attack (Kimmey and Furniss, 1943), it is imperative that salvage operations be started as quickly as possible. If prompt utilization of all timber is not possible then injured trees may be risk-rated and the cutting operations modified to minimize expected losses from wood-boring insects.

Fire-killed trees differ in their degree of charring and foliage consumption, and many authors have recorded different intensities of wood borer attack with degree of fire damage. Trägårdh (1929), Simpson (1951), and Kimmey (1955) did not erect burn-damage categories, but observed different attack intensity between severely burned trees and lightly burned trees. Skolko (1947), Gardiner (1957), Prebble and Gardiner (1958), and Ross (1960) classified fire-damaged trees into 3 categories, while Salman (1934), used four categories, and Richmond and LeJeune (1945), five categories. All these authors recorded that density of wood borers was affected by degree of fire-damage to the tree. I find it convenient to recognize three classes of Burn Types and to discuss the risk and expected density of beetle attack of each Burn Type.

<u>Class I</u>: Severe Burn Type

Bark moderately to severely charred throughout the length of the bole and on all sides. Needles completely consumed by the fire.

<u>Class II</u>: Moderate Burn Type

Trees severely charred at base and bark of lower 1/3 of bole charred. Needles brown but present within a month after the burn.

<u>Class III</u>: Light Burn Type

Trees with little charring at base, usually only up to breast height; charring usually does not extend all the way around the tree. Usually

20% to 50% of needles brown (Usually all the needles will turn brown within 2 months).

Borer activity in these classes will vary depending upon the time of the year the fire occurred.

A. Spring or Early Summer Fires (up to August 1)

Class I and Class II trees. - Both these classes are very attractive to adult beetles and oviposition occurs wherever the bark is tight (Gardiner, 1957; Richmond and LeJeune, 1945). But survival is poor in Class I trees since at least 65% of the larvae die in the early instars (Raske, unpublished data). But the survivors in Class I trees are at times numerous enough to cause economic damage. Checking often becomes a serious problem the second season in the severely burned trees in Class I. The larvae in trees in Classes I and II will begin to enter the wood by late August. These trees, if cut and processed by August, will yield 'worm-hole' free lumber. Generally, Class II trees will be the most severely damaged by wood-boring insects (Prebble and Gardiner, 1958; Richmond and LeJeune 1945; Ross, 1960), and maximum damage in these trees will be reached by October of the first season.

Class III trees. - A large percentage of these trees are generally not suitable for egg-laying until the following year when they may be heavily attacked. (Gardiner, 1957; Richmond and LeJeune, 1945). These trees should be utilized by August of the second year.

B. Late Summer and Fall Fires (after mid-August)

Data showing the insect deterioration of trees killed by fall fires is not available to the best of my knowledge. Ross (1960) found that fire-killed spruce in British Columbia from July 15 to August 12, was unattacked by wood borers, and he observed that the fire occurred after the beetle flight in that area. However, since fall fires are common in Alberta, the hazards of wood borer damage are surmised from observations in burned areas in Alberta and the habits of wood boring insects.

Class I trees. These trees would be too dry to be attractive to any wood borers by the following June when the next flight of beetles will occur, and will therefore not be attacked. But checking may begin during the first summer after the fire.

Class II trees. A light to medium infestation in about half of the trees in this category can be expected in the summer after fire. The other half of the trees will be too dry to be attractive.

Class III trees. These generally are likely to be heavily attacked the following season. Any logs that can be cut and processed by mid-August of the following season will be free of worm holes.

C. General

Preventive chemical treatment of decked logs, or even standing trees is probably just as effective for fire-killed timber as it is for unburned logs (Simpson, 1951), and treatment could be considered for trees not likely to be damaged by checking, if they cannot be salvaged in time.

RESEARCH NEEDED

Control of wood-boring insects is a rather new field of investigation and much experimental work is still needed before we have answers for the variety of circumstances that confront the lumber industry. More experimental control work should be done with PDB, which shows promise of having wide application as an effective fumigant against wood-boring insects. Foremost is the need to study the wood-penetrating ability of PDB and its rate of spread within large-size decks of logs. Experimental work is needed to test crystalline PDB as a preventative treatment. PDB acts as an insect repellent, and this property needs to be tested on adult females as they fly in to lay eggs. Both dosage and frequency per season need testing.

Export lumber has been rejected by agricultural inspectors because of the presence of adult wood borers in railroad box cars and not because of the presence of 'worm holes' in the lumber. PDB should be tested for its ability to penetrate stacked lumber in close containers, and kill wood borers still within the lumber.

For many reasons it is desirable that chemical control be eliminated and that non-chemical methods be used to solve our wood borer problems. Basic research is needed to answer questions as to why a wood borer is attracted to a log. The answer to the question of why one log is attractive and another log not attractive is becoming urgent. We need to know if wood borers have a congregating pheromone. We need to know what chemicals in the bark attract the wood borers to a tree. Once we have answers to these questions then we might be able to proceed with effective control measures without putting chemicals into the environment.

LITERATURE CITED

Allen, D.G., and Y.A. Rudinsky. 1959. Effectiveness of Thiodan, Sevin, and Lindane on insects attacking freshly cut Douglas-fir logs. J. Econ. Ent., 52: 482-484.

Basham, J.T. 1957. The deterioration by fungi of jack, red, and white pine killed by fire in Ontario. Can. J. Bot. 35:155-172.

Beal, J.A., J.W. Kimmey, and E.F. Rapraegar. 1935. Deterioration of killed Douglas fir. Timberman 37:12-17.

Becker, W.B. 1955. Tests with BHC emulsion sprays to keep boring insects cut of pine logs in Massachusetts. J. Econ. Ent. 48:163-167.

____________ 1958. Benzene hexachloride sprays to protect sawlogs from insects. Co-operative extension service. University of Massachusetts, Amherst.

____________ 1962. Autumn versus spring spraying of unseasoned red pine logs with BHC. J. Econ. Ent. 55:1020-1021.

____________ 1964a. Tests with endosulfan to prevent borer damage to unseasoned pine logs. J. Econ. Ent., 57: 166-167.

____________ 1964b. Autumn versus spring spraying to combat insect pests of unseasoned pine logs. J. Forestry, 62:386-388.

Becker, W.B., and H.G. Abbott. 1960. Lumber down grading losses due to insect damage to small unseasoned pine sawlogs. J. Forestry, 58: 46-47.

____________________________ 1961. Prevention of insect damage to decked pine sawlogs in Massachusetts with BHC emulsion sprays. J. Forestry, 59:366-369.

Becker, W.B., and H.G. Abbott. 1966. Autumn spraying of decked pine sawlogs to prevent insect damage. J. Forestry 64:387-389.

Becker, W.B., H.G. Abbot, and J.H. Rich. 1956. Effect of lindane emulsion sprays on the insect invasion of white pine sawlogs and the grade yield of the resulting lumber. J. Econ. Ent. 49:664-666.

Belyea, R.M. 1952. Death and deterioration of balsam fir weakened by spruce budworm defoliation in Ontario. Can. Ent. 84:325-335.

Carpenter, B.E. Jr., and E.R. Toole. 1963. Sprinkling with water protects hardwood logs in storage. South. Lumberman, 207(2576); 25-26.

Chesley, K.G., J.C. Hair, and J.N. Swartz. 1956. Underwater storage of southern pine pulpwood. Tappi, 39:609-614.

Craighead, F.C. 1923. North American cerambycid larvae. Dom. Can. Dept. Agr., Tech. Bull. No. 27-N.S., 130 pp. 44 pl.

_______________ 1950. Insect enemies of eastern forests. U.S. Dept. Agr., Misc. Publ. 657, 679 pp.

Dillon, L.S., and E.S. Dillon. 1941. The tribe Monochamini in the western hemisphere. Reading Publ. Mus. and Art. Gallery, Sci. Publ. No. 1, 135 pp., 5 pl.

Dobie, J. 1965. A review of log storage practices. British Columbia Lumberman 49:16-17, 64-66.

Drury, H.J.R. 1954. The European house borer (<u>Hylotrupes bajulus</u>) and its control in the western Cape Province. S. Afr. Dept. Agric. Bull 337.

Furniss, R.L. 1937. Salvage on Tillamook burn as affected by insect activity. Timberman, 39:11-13, 20, 32.

Fystro, V.I., and A. Bakke. 1962. Damage on unbarked coniferous sawlogs and the effect of chemical spraying during summer storage in forest in different parts of Norway. Norsk. Skogbruk, 8:272-278 (English Summary).

Gardiner, L.M. 1957. Deterioration of fire-killed pine in Ontario and the causal wood-boring beetles. Can. Ent. 89:241-263.

__________ 1962. Survival of wood borers in water-stored logs. For. Chron., 38:459-462.

__________ 1970. New northern Ontario spruce beetle compels May start on log spraying. Can. For. Ind., July 1970, 3 pp.

Graham, S.A. 1952. Forest Entomology. McGraw-Hill Book Co., New York.

Harris, J.W.E., J. Grant, and H. Richmond. 1968. Assessment of wood borer control trials, Mackenzie, British Columbia. Can. For. Serv., For. Res. Lab., Victoria, B.C. Information Rept. BC-X-21.

Hedlin, A.F., and T.A.D. Woods. 1970. Experiments in preventive treatment of Douglas fir against attack by the ambrosia beetle (Trypodendron lineatum) (Oliv.) using benzene hexachloride, methyl trithion, and other insecticides. Can. For. Serv., For. Res. Lab., Victoria, B.C., Internal Report BC-18 (Unpublished).

Hopping, R. 1921. A review of the genus Monochamus Serv. (Cerambycidae, Coleoptera). Can. Entomol., 53:252-258.

Keen, F.P. 1952. Insect enemies of western forests. U.S. Dept. Agr., Misc. Publ. No. 273, 280 pp.

Keino, K. 1969. Studies on the protection of freshly cut japanese pine logs against fungus and insect attacks. Bull. Govt. For. Exp. Sta. No. 223, 25-68. 4 pl., Tokyo, Japan (English Summary).

Kimmey, J.W. 1955. Rate of deterioration of fire killed timber in California U.S. Dept. Agr., Circ. 962, 22 pp.

Kimmey, J.W., and R.L. Furniss. 1943. Deterioration of fire-killed Douglas fir. U.S. Dept. Agr., Tech. Bull. 851, 61 pp.

Linsley, E.G. 1961. The Cerambycidae of North America, Part I. Univ. of Calif. Publ. in Ent., Vol. 18, 97 pp., 35 pl.

__________ 1962. The Cerambycidae of North America, Part II. Univ. of Calif. Publ. in Entomol., Vol. 19, 102 pp., 1 pl.

Lyon, R.L. 1965. Structure and Toxicity of insecticide deposits for control of bark beetles. U.S. Dept. Agric., Techn. Bull. No. 1343, 59 pp.

Mason, R.R., J.M. Mahonen, and J.N. Swartz. 1963. Water sprayed storage of southern pine pulpwood. Tappi, 46:233-240.

Morgan, C.V.G. 1948. The biology of *Monochamus notatus morgani* (Coleoptera: Cerambycidae). Ent. Soc. Brit. Columbia, 44:28-30.

Parmelee, F.T. 1941. Longhorned and flat headed borers attacking fire-killed coniferous timber in Michigan. J. Econ. Entomol., 34:377-380.

Prebble, M.L., and L.M. Gardiner. 1958. Degrade and value loss in fire-killed pine in Mississagi area of Ontario. For. Chron. 34:139-158.

Prentice, R.M., and A.E. Campbell. 1959. Volume loss of pulpwood in Manitoba caused by wood borers. For. Chron. 35:142-145.

Raske, A.G. 1972a. Taxonomic relationship between Monochamus scutellatus and M. oregonensis (Coleoptera:Cerambycidae). Submitted to Can. Ent.

____________ 1972b. Tetropium parvulum elevated to species and contrasted to T. cinnamopterum in morphology and host preference (Coleoptera:Cerambycidae). Submitted to Can. Ent.

____________ 1972c. Wood borer control with plastic sheeting with paradichloro benzene in conifer logs (Coleoptera:Cerambycidae). J. Econ. Ent. (in press).

____________ 1972d. Effects of felling date on density of Monochamus in pine and spruce logs (Coleoptera: Cerambycidae).

Raske, A.G., and L. Safranyik. 1970. Sequential sampling plan for determining infestation and damage levels of Monochamus (Coleoptera:Cerambycidae) wood borers in decked lodgepole pine logs in Alberta. Can. For. Serv., For. Res. Lab., Calgary, Alta., Internal Rept. A-26.

Raymond, F.L., and J. Reid. 1961. Dieback of balsam fir in Ontario. Can. J. Bot. 39:233-251.

Richmond, H.A. 1967. Ambrosia beetle control. Pacific Logging Congress. Logger's Handbook 27:59-62.

____________ 1969. A new chemical for the protection of logs from ambrosia beetle attack. Rept. Council For. Ind. Brit. Columbia.

Richmond, H.A., and R.R. LeJeune. 1945. The deterioration of fire-killed white spruce by wood-boring insects in northern Saskatchewan. For. Chron. 21:168-192.

Roff, J.W. 1967. A record of _Tetropium cinnamopterum_ Kirby in white spruce logs in central British Columbia. Can. For. Serv. Bi-monthly Res. Notes. 23:27.

Roff, J.W., and J. Dobie. 1968. Water sprinklers check biological deterioration in stored logs. Brit. Columbia Lumberman, 52,6pp.

Rose, A.H. 1957. Some notes on the biology of _Monochamus scutellatus_ (Say) (Coleoptera:Cerambycidae) Can. Ent. 89:547-553.

Ross, D.A. 1960. Damage by longhorned wood borers in fire-killed white spruce, central British Columbia. For. Chron. 36:355-361.

__________ 1966. Biology of the spotted pine sawyer _Monochamus maculosus_ (Haldeman) (Coleoptera:Cerambycidae). Can. For. Serv., For. Res. Lab., Victoria, B.C., Internal Rept. BC-5.

__________ 1967. The western larch borer _Tetropium velutinum_ LeConte, in interior British Columbia. J. Entomol. Soc. Brit. Columbia, 64:25-28.

Ross, D.A., and J.S. Downton. 1966. Protecting logs from longhorned wood borers with Lindane emulsion. For. Chron. 42:377-379.

Ross, D.A., and N.J. Geistlinger. 1968. Protecting larch logs from _Tetropium velutinum_ LeConte with Lindane emulsion. J. Ent. Soc. Brit. Columbia. 64:14-15.

Ross, D.A., and H. Vanderwal. 1969. A spruce borer, _Tetropium cinnamopterum_ Kirby, in interior British Columbia. J. Ent. Soc. Brit. Columbia. 66:10-14.

Safranyik, L. and A.G. Raske. 1970. Sequential sampling plan for _Monochamus_ larvae in decked lodgepole pine logs (Coleoptera: Cerambycidae) J. Econ. Ent. 63:1903-1906.

Salman, K.A. 1934. Entomological factors affect salvaging of fire injured trees. J. Forestry, 32:1016-1017.

Simpson, L.J. 1951. Prevention of damage by borers in softwood logs or fire-killed timber. Can. Dept. Agr., Sci. Serv., Div. For. Biol., Processed Publ., Ottawa, 5 pp.

Skolko, A.J. 1947. Deterioration of fire-killed pulpwood stands in eastern Canada. For. Chron. 23:128-145.

Smith, V.K. Jr. 1965. Protecting logs, bolts, and chips from insects. In Insects in Southern Forests, C.B. Marlin, ed. Fourteenth Annual Forestry Symposium, Louisiana State University Press, pp. 125-129.

Solomon, J.D. 1969. Woodpecker predation on insect borers in living hardwoods Ann. Ent. Soc. Amer. 62:1214-1215.

Soper, R.S., and R.E. Olson. 1963. Survey of biota associated with Monochamus (Coleoptera:Cerambycidae) in Maine. Can. Ent. 95:83-95.

Tooke, F.G.C. 1948. The use of preservatives against wood destroying insects. Farm. in S. Afr., April 1948.

Tothill, J.D. 1924. Injury to fire-killed lumber in New Brunswick by the softwood borer. New Brunswick Land Dept., Ann. Rept. 63:86-87.

Tragardh, I. 1929. Om tallbockens skadegorelse och bekampande. Meddel. fran. Statens Skogsforskosanstalt 25:171-228 (English Summary).

Vanderwal, H., and D.A. Ross. 1968. Log preference studies on Tetropium velutinum LeConte. Can. For. Serv., Bi-Mon. Res. Notes 24:31.

White, M.G. 1967. Wood preservatives dip treatment tests against house longhorn beetle. International Pest Control 9:18-23.

Wickman, B.E. 1965. Black-headed three-toed woodpecker, Picoides arcticus predation on Monochamus oregonensis (Coleoptera: Cerambycidae) Pan-Pac. Ent. 41:162-164.

Wilson, L.F. 1960. Reducing pulpwood losses from borer attacks by shading conventional pulp piles. U.S. Dept. Agr., Lake States For. Exp. Sta., Technical Note No. 583, 2 pp.

__________ 1961. Attraction of wood-boring insects to freshly cut pulpstocks. U.S. Dept. Agric., Lake States For. Exp. Sta., Tech. Notes No. 610, 2 pp.

__________ 1962. White-spotted Sawyer. U.S. Dept. Agr. Lake States For. Exp. Sta., Forest Pest Leaflet No. 74, 7 pp.

Fig. 1. Egg niche of *Monochamus scutellatus oregonensis* in white spruce (scale in mm).

Fig. 2. Outer bark cut away to show egg of *Monochamus s. oregonensis* in white spruce (scale in mm).

Fig. 3. Mature larvae of *Monochamus scutellatus scutellatus* (X2).

Fig. 4. Head capsule of *Monochamus s. scutellatus*.

Fig. 5. Pupa of *Monochamus s. oregonensis*, a) dorsal, b) ventral (X3).

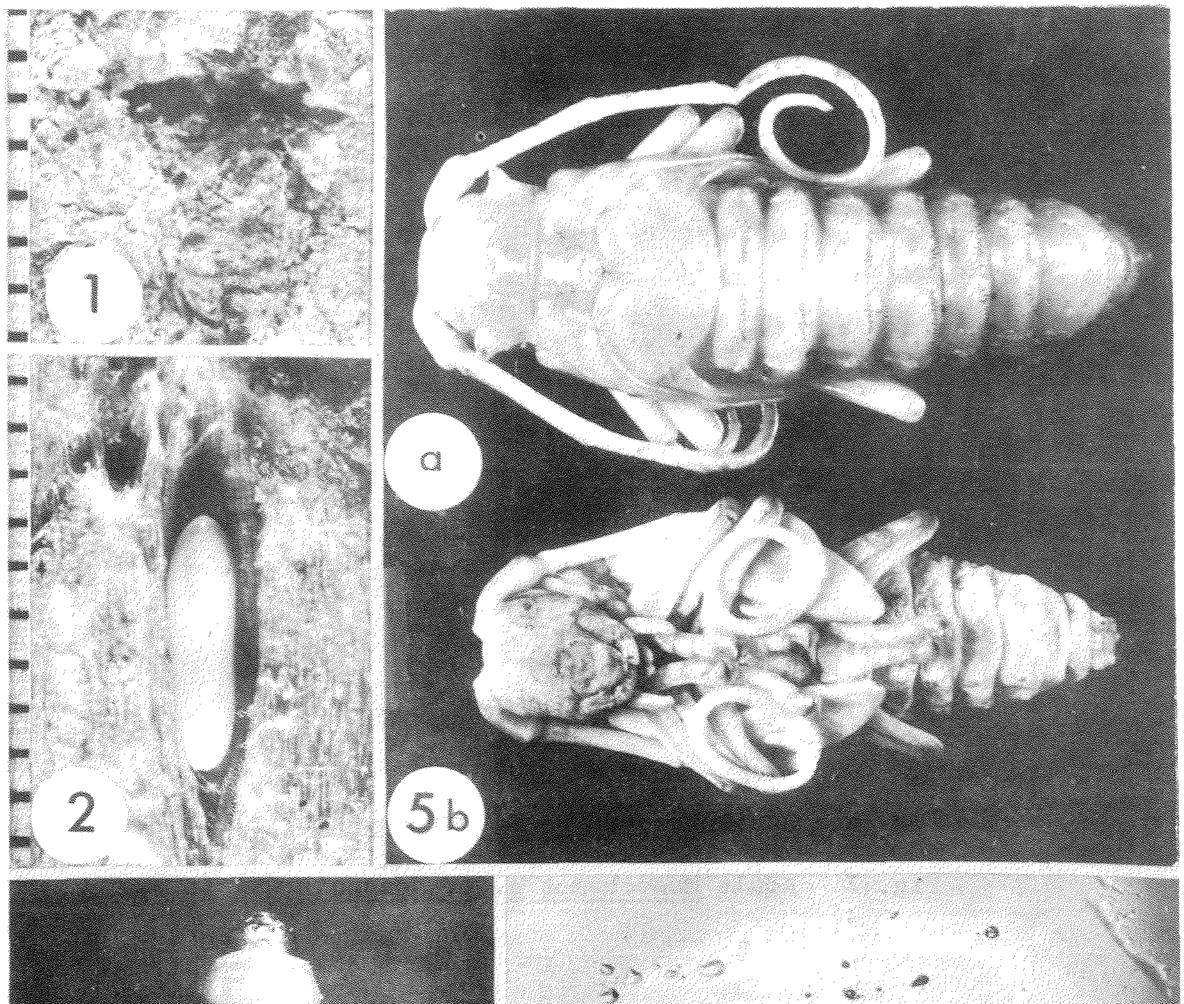
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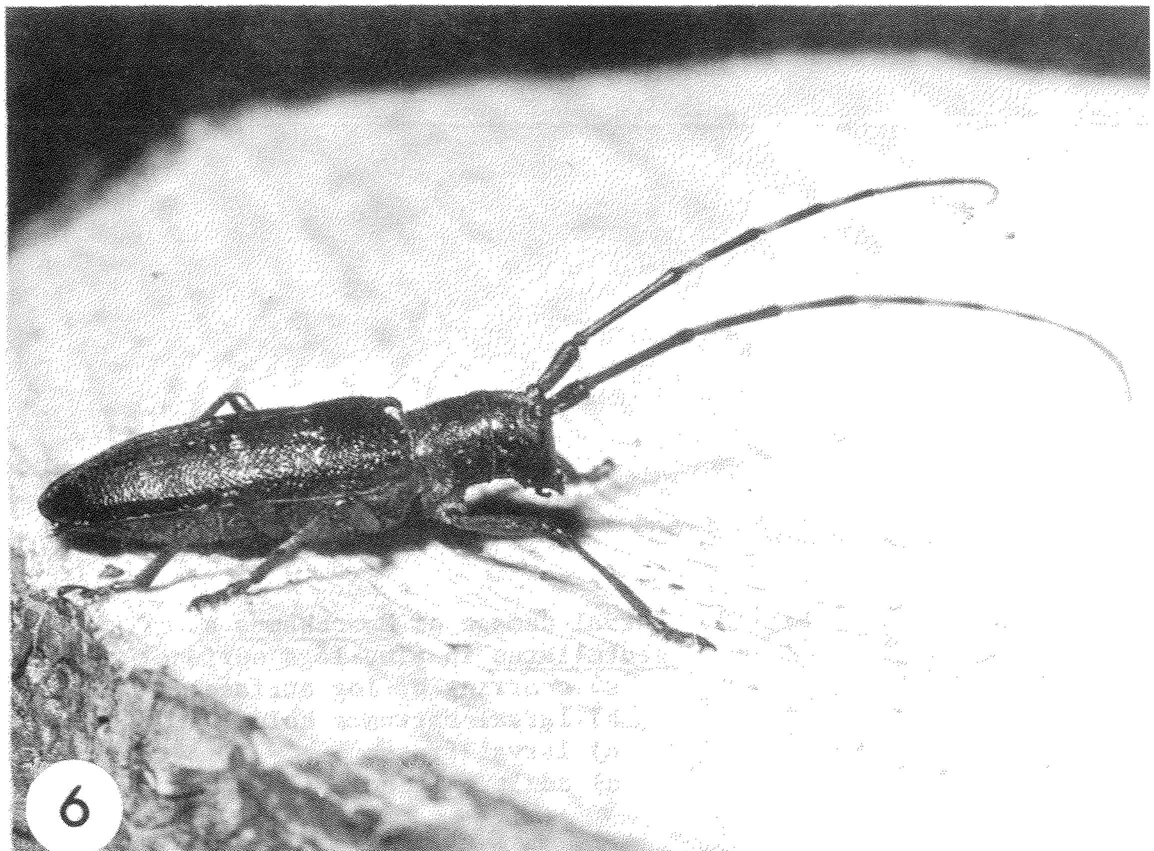
Fig. 6. Adult *Monochamus s. oregonensis* (♀) (X2).

Fig. 7. Adult *Monochamus s. oregonensis* (♂) (X2).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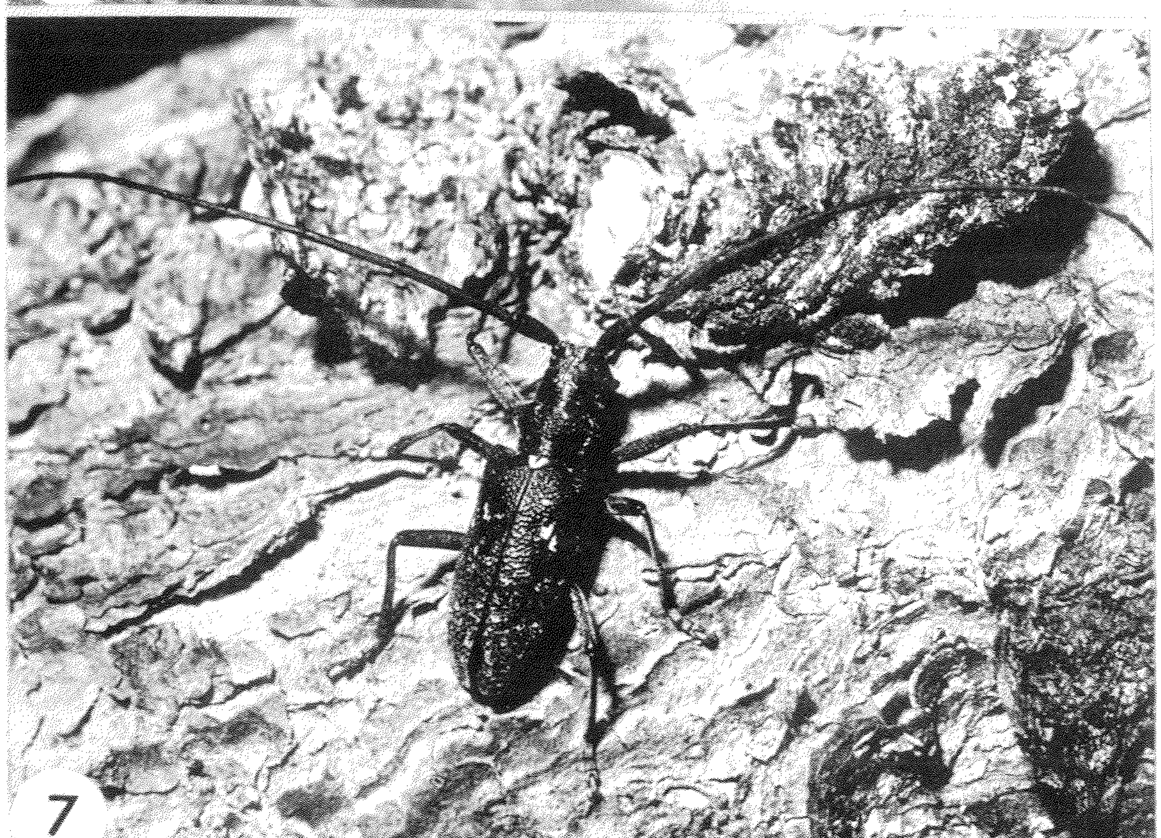
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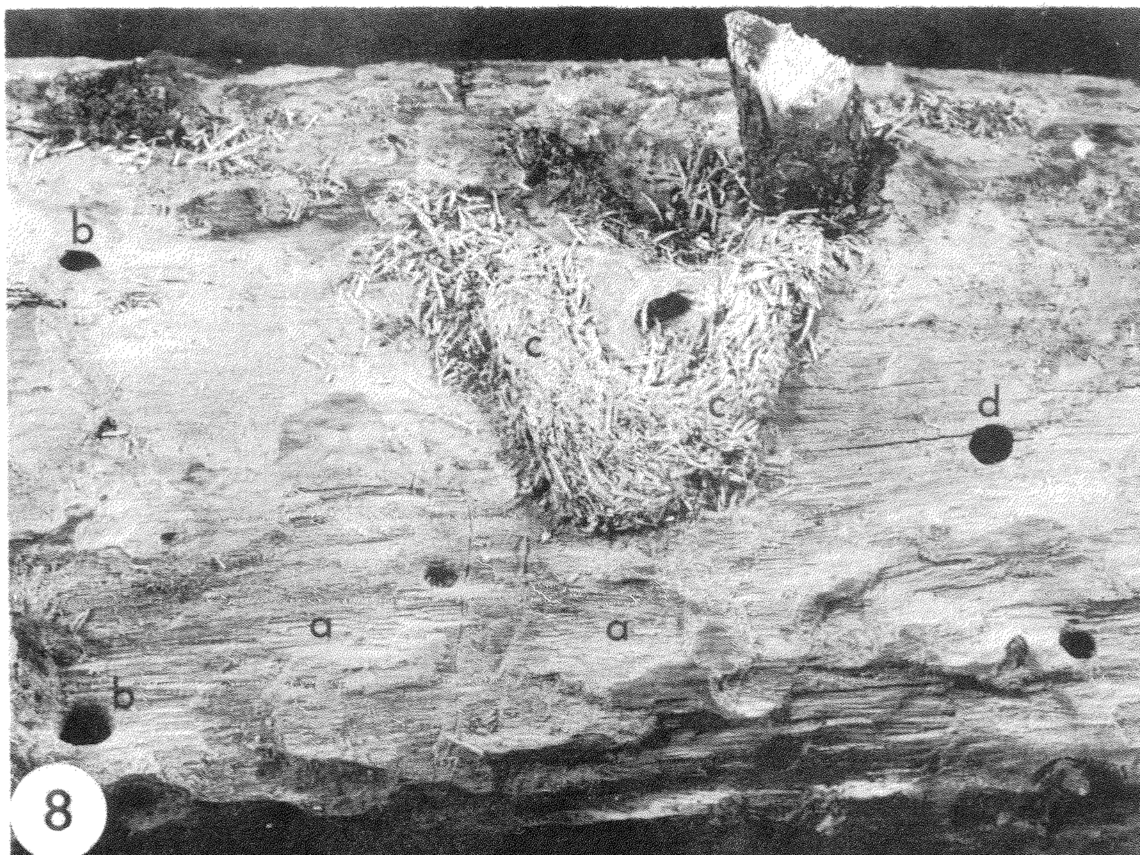
Fig. 8. Larval damage of *Monochamus s. scutellatus* in pine logs surface,
- a) scarring of log surface;
- b) larval entrance hole;
- c) larval frass;
- d) adult exit hole (X½).

Fig. 9. Split pine log showing larval damage of *Monochamus s. scutellatus*;
- a) larval mine;
- b) pupal cell (X½).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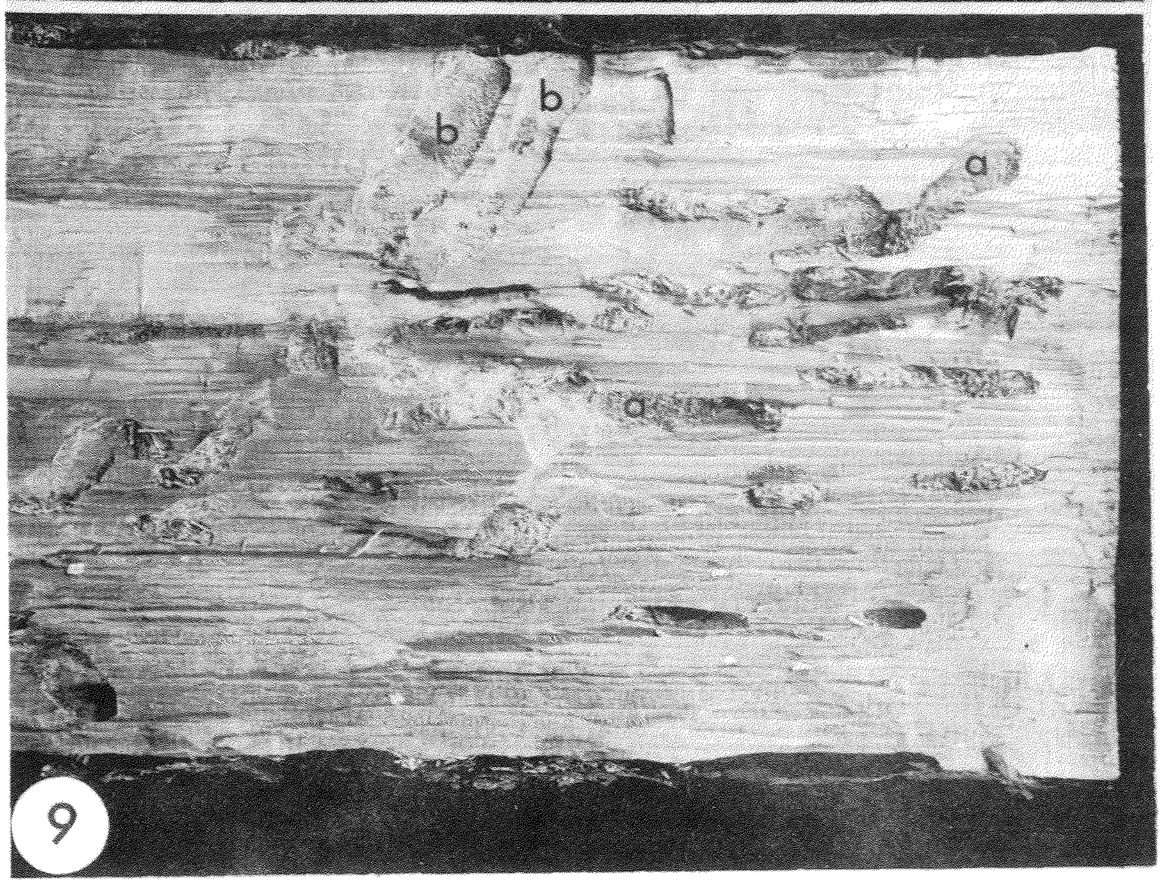
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Fig. 13. Larval patch-like feeding pattern of *T. parvulum* on log surface of white spruce (X1¼).

Fig. 14. "L"-shaped larval mine and pupal cell of *T. parvulum* in white spruce (X2).

Fig. 15. Dead larva of *T. parvulum* overgrown by fungus (X1).

Fig. 16. Parasite cocoon of *T. parvulum* in *Tetropium* pupal cell (X1).

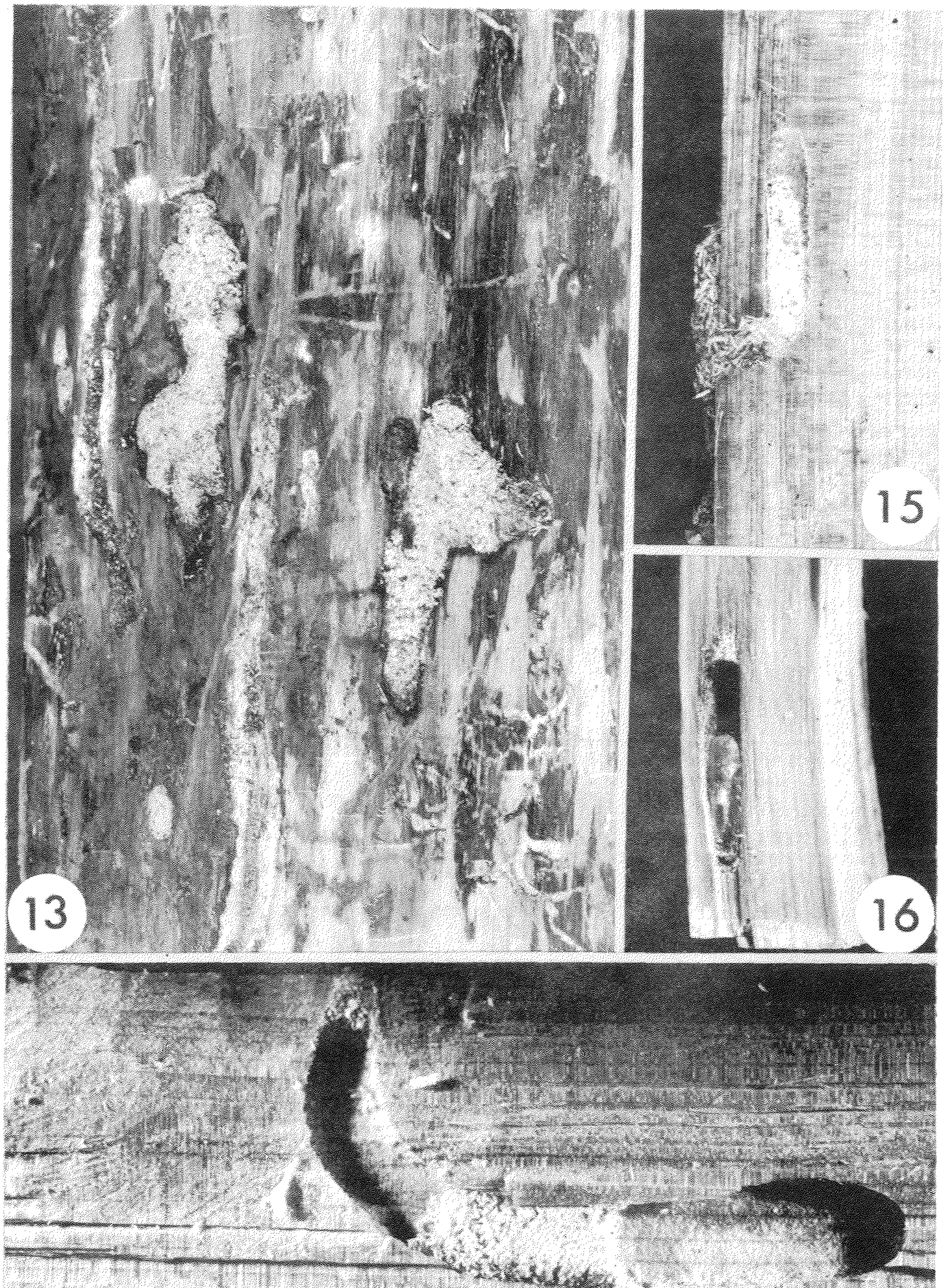
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Fig. 17. Adult T. paravulum (♂) (X4).