# A STUDY OF SOME WOOD-BORING COLEOPTERA ATTACKING FIRE-KILLED CONIFEROUS TREES IN MICHIGAN

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# A STUDY OF SOME WOOD-BORING COLEOPTERA ATTACKING FIRE-KILLED CONIFEROUS TREES IN MICHIGAN

by

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# INTRODUCTION

Kellogg (55) reported the original forest area of the United States as 850,000,000 acres containing 5,200,000,000,000 board feet of saw-timber. Due to clearings, fires, insect depredations, storms, disease and other causes, this vast acreage had been reduced to 550,000,000 acres containing 2,500,000,000,000 board feet of saw-timber by 1909. Recent surveys by Garver (27) show the present acreage to be about the same as that of 1909 containing, however, only about 1,800,000,000,000 board feet of saw-timber. The above statistics show that our forest resources are not inexhaustible notwithstanding our present day reforestation and conservation activities. While our total forest area has not decreased alarmingly since the beginning of the century, a large part of our choice timber has been removed.

## INSECT LOSSES TO FORESTS AND FOREST PRODUCTS

Hopkins (44) quotes Professor Lawrence Bruner, State Entomologist of Nebraska as saying: "I can agree with Doctor Hopkins that the insects are far more important in destroying our forests than fires." The countless hordes of tree-killing and wood-destroying insects exact an enormous toll, and were

it not for rigorous control measures practiced in various parts of the country, timber losses would be far in excess of present figures.

Bark beetles, especially those of the genus Dendroctonus, and defoliating insects such as the spruce budworm and larch sawfly are responsible for the major part of our forest losses. Hopkins (44) reports that the Black Hills beetle, Dendroctonus ponderosae Hopk., destroyed about one billion board feet of coniferous timber over a ten year period, which at $2.50 per thousand board feet, would mean an annual loss of $250,000. This is an example of the destructiveness of but one species of bark beetle in one national forest. Hopkins (44) bases the insect losses on 10% of the mature trees impossible to utilize. At $2.50 per thousand board feet, he believes $62,500,000 to be a conservative estimate of the annual loss. Hyslop (53) reports forest insect losses to be variously estimated at around $100,000,000 annually. Graham (34, p. 11) assuming a 10% loss of the annual cut for the years 1925-1929 finds the yearly loss to be 5,913,383,900 board feet.

Forest insects such as certain bark beetles and defoliators are classed as primary forest enemies in that they attack living trees (34, p. 202). To this group of insects is attributed the bulk of the forest damage. However, secondary forest insects, that is, those that attack only dead or dying timber, occasionally cause heavy damage. The larvae or "grubs" of these secondary species, belonging chiefly to the families Cerambycidae, Scolytidae and Buprestidae of the order Coleoptera, excavate cavities in the sapwood and bore tunnels

into the heartwood of dead or dying timber either completely destroying or greatly reducing in value a product which otherwise would be highly merchantable. Hopkins (43) states that the aggregate losses from this damage in the coniferous forests of the United States contribute largely to the annual waste of millions of dollars in forest products, which without the injury might easily be utilized.

Timber killed by primary insects, fire, storms, disease and other causes are readily attacked and greatly damaged by the depredations of secondary borers. Dead coniferous timber, especially if it is standing, has been found to be in an excellent state of preservation for long periods after death, provided no insect damage has occurred. Hopkins (44) found pines, spruces, larch and Douglas fir killed by insects and fire, and which had escaped borer damage, to be entirely suitable for lumber, fuel, pulp and railroad ties from 20 to 30 years after death. In localities where fires, storms or other agencies have killed large areas of timber, especially in the spring or early summer, prompt utilization, barking or submerging in water is often impossible. Wood-boring insects together with fungi which are allowed to reach the heartwood through the borers' tunnels rapidly cause the deterioration of such timber. Losses may be as high as 50% in three months and commonly 100% in three or four years. (18), (42), (43), (45). Webb, (90) (91), reported damage in excess of $6,000,000 to storm-felled pine in the South by one species of sawyer, Monochamus titillator (Fab.). Secondary insect damage to felled trees

following the New England hurricane in 1938 was also considerable (25).

ATTRACTION OF FRESHLY KILLED TREES TO CERTAIN COLEOPTERA

Most trees, especially coniferous, are attractive to wood borers if cut or killed shortly before or during the time in which the adults are flying; such timber is almost certain to become infested. Timber dying late in the summer or fall is not nearly so heavily damaged, especially in the northern forests. (9), (45), (87). Graham (32) states that green wood is necessary for the early larval stages of Cerambycidae and Buprestidae. From this it would appear that the period between the death of the tree and dessication of the inner bark and cambium is the most suitable time for successful infestation.

Fire-killed or scorched coniferous trees apparently have an attraction for certain insects. The smoke or the odor of the burning bark and needles probably serve as attractants but definite proof as to this is lacking. (49), (74). Doane, Van Dyke, Chamberlin and Burke, (20, p. 18), report that one Buprestid borer, Melanophila consputa Lec., cannot even wait for the trees to cool off but flies through the smoke and deposits its eggs on the still smouldering trunks. This species is said to annoy fire fighters by pinching them on the neck and hands. St. George and Beal (78) found beetles attracted to burned areas within a radius of three or four miles and in Sweden, Tragardh, (88), states that sawyer beetles are attracted for miles by fire, ovipositing first on the largest and most severely scorched trees. Trees scorched all around are most

attractive, he says, and only the scorched side of the tree will be attacked.

## BURNED-OVER AREAS AND SOURCES OF EPIDEMIC INFESTATIONS

Various results have been reported on the possibility of epidemic infestations arising from burns, slash depositions and other favorable breeding places. Miller and Patterson, (62), report fire-killed and fire-injured timber as highly attractive to the western pine beetle, Dendroctonus brevicomis, resulting in heavy concentrations within the burn. Such concentrations, they say, do not develop into epidemics but, on the contrary, return to normal within three or four years. Fires attract beetles but conditions are not favorable for breeding in the burned-over areas. They point out that the sudden interruption and disturbance of the sap flow in burned trees causes an extreme moist condition of the inner bark which is unfavorable for the young bark beetle larvae, causing the death of many of them; in some of these trees, fewer beetles emerge than attack them. Many trees, however, are only moderately injured by the fire and apparently are able to recover. Such trees are readily and successfully attacked by bark beetles; in this way only, are they believed to supplement and increase losses initiated by fire. According to Bureau of Entomology reports for 1919 (50) the infestation of beetles within a certain small burned-over area increased up to 1000%, but the numbers in the surrounding areas decreased and the whole area returned to a normal condition within a comparatively short period of time. These reports agree with those of Miller and Patterson in that fire-

injured trees suffer heavily from insect attack. Investigations in this country indicate that neither infested slash nor burned areas become foci for epidemic infestations, (17), (30), (46), (64).

In Russia, several investigators have reported fires as becoming a source of infestation affecting healthy trees. Sokanovskii (76) reports migration of bark beetles to healthy spruce after removal of dead and severely damaged host trees from a burned-over coniferous area; Stark and Ctaph (79) say development of bark beetles and other insects in large numbers in a coniferous forest fire area is always followed by intensive flight to surrounding healthy trees and Porozorov (68) reports beetles as multiplying in certain parts of burnt areas of Russian timber followed by migration to healthier trees.

## OBJECTIVES

This investigation has been concerned with a study of some of the secondary wood-boring beetles contributing to the deterioration of fire-killed coniferous timber in Michigan. Most of the effort has been toward the end of determining what borers are present in such areas and the part each plays in the eventual destruction of the wood. From time to time examinations were made of both the fire-injured and uninjured trees within and bordering the burned-over areas to determine the effect of such concentrated infestations on the surrounding forest. Observations of insect infestations in slash and storm-felled timber, for purposes of comparison, were thought worth while. While it

is obvious that a study of this nature over a period of two or three years is much too short for completeness, it is hoped that this paper will bring out the importance of a group of insects which are commonly associated together in fire-killed timber.

## METHODS AND EQUIPMENT

Infested material was cut from the burned-over areas, brought to the laboratories at East Lansing and placed in screen cages of a mesh size adequate to prevent escape of the smaller insects. For each cage of material left out of doors under natural conditions, a corresponding cage of material from the same tree was placed indoors. Each was given a number so as to indicate that the wood came from the same tree. Individual records were kept for all trees brought to the laboratory. Each insect emerging from the wood in the various cages was given its proper number and date of emergence. In addition the smaller branches of at least one tree of each species was kept separate from the larger limbs and butt portions of the trunk in order to determine the prevalence, if any, of certain insects in different parts of the tree.

## PROCEDURE

The collection of material for this study was begun in the fall of 1937 and continued through 1938 and 1939, during which time several truck and trailer loads of infested fire-killed

coniferous timber was cut in Northern Michigan and brought to the laboratories at East Lansing for study. Dead wood from the following trees were cut into suitable lengths, placed in cages and labeled in a manner already described: white pine (Pinus strobus L.), Norway or red pine (Pinus resinosa Ait.), jack pine or scrub pine (Pinus banksiana Lamb.), balsam fir (Abies balsamea (L.) Mill.), American larch or tamarack (Larix laricina (Du Roi) Koch.) and black or bog spruce (Picea mariana (Mill.) B. S. P.).

The wood caged indoors was kept in a greenhouse at a temperature of between 60 -70 F. The moisture content of the material was kept as favorable as possible for the immature insects by weekly applications of water. The presence of red ants in the greenhouse caused difficulty, especially during the first year. These voracious insects penetrated deep into the heartwood and devoured many of the helpless larvae. Further trouble from this source was prevented by a thorough clean-up of hiding places and by placing the cages on long, low, rack-like tables supported by legs immersed in shallow pans of oil. Tanglefoot was smeared on the supporting rack between cages so as to prevent migration of the ants from cage to cage. Very few ants were observed in 1938 and none during 1939-1940. Precautions were also observed in protecting the out-of-door cages against ants but apparently they are not so much of a problem there as indoors.

## MATERIAL COLLECTED IN 1937

No fire-killed coniferous wood from spring fires was available during this year. Material from spring fires is desirable because of its attractiveness to the female beetles for purposes of oviposition during the months in which they are flying, (May, June and July). However, material for study during this year was obtained in the following manner: Sections from the base and larger branches of white pine trees in the vicinity of East Lansing, Michigan were scorched by burning a light application of old crank-case oil smeared over the surface. These trees were in a weakened condition due to a heavy infestation of the bark beetles, Ips calligraphus (Germ) and Ips pini (Say) and were felled by the Forestry Department of Michigan State College in the early spring only because their death appeared imminent. On May 13, 1937, after the superficial burning described above, the logs and limbs were placed in a sunny spot near a quantity of pine fire-wood which had been infested with wood-boring insects during the previous year. A similar amount of recently-felled white pine wood which had not been given the burning treatment was distributed at the same time in the same locality. All wood was collected and caged on September 20, 1937. Portions of both burned and unburned wood was placed in the greenhouse for winter observations with the remainder being left out-of-doors. At the time of caging, examination proved all pieces of wood to be infested except two fire-treated limbs of about four inches in diameter.

By September 20, most of the borer larvae had finished their phloem region feeding as was evidenced by oval-shaped entry holds into the sapwood. In spite of this protection, red ants destroyed a number of the larvae in the wood of the greenhouse cages.

## 1937 RESULTS

The following two pages are devoted to a record of secondary beetles reared from white pine (Pinus strobus L.), exposed to infestation as described under "Material Collected in 1937."

## Table I. WOOD CAGED INDOORS

| Species of insects reared from 4 logs 3 ft. long, average diameter 6½ in. Total approximate surface 20 sq. ft. | Number Reared | | Emergence Dates | | Average no. beetles per sq. ft. of bark surface | |
|---|---|---|---|---|---|---|
| | Burned | Not burned | Burned | Not burned | Burned | Not burned |
| Monochamus scutellatus (Say). | 17 | 21 | 12/29/'37 to 2/23/'38 | 12/26/'37 to 2/16/'38 | .85 | 1.05 |
| Pogonocherus mixtus Hald. | 19 | 11 | 12/20/'37 to 1/28/'38 | 12/23/'37 to 1/26/'38 | .95 | .55 |
| Astylopsis guttata (Say) | 5 | 13 | 1/3/'38 to 3/2/'38 | 12/28/'37 to 2/17/'38 | .25 | .65 |
| Asemum moestum Hald. | 0 | 0 | - | - | - | - |
| Chrysobothris dentipes Germ. | 2 | 6 | 1/27 to 2/6/'39 | 1/24 to 1/31/'39 | .10 | .30 |
| Total | 43 | 51 | | Average | 2.15 | 2.55 |
| Species of insects reared from 4 limbs 3 ft. long, average diameter 3½ in. Total approximate surface 10 sq. ft. | | | | | | |
| Monochamus scutellatus (Say). | 6 | 3 | 12/27/'37 to 2/10/'38 | 12/26/'37 to 2/18/'38 | .60 | .30 |
| Pogonocherus mixtus Hald. | 3 | 4 | 12/24/'37 to 1/26/'38 | 12/23/'37 to 1/27/'38 | .30 | .40 |
| Astylopsis guttata (Say.) | 5 | 7 | 1/3/'38 to 2/26/'38 | 1/3/'38 to 2/20/'38 | .50 | .70 |
| Asemum moestum Hald. | 0 | 8 | - | 1/17/'38 to 1/22/'38 | 0 | .80 |
| Chrysobothris dentipes Germ. | 7 | 6 | 1/27 to 2/9/'39 | 1/27 to 2/26/'39 | .70 | .60 |
| Totals | 21 | 28 | | Average | 2.10 | 2.80 |

## Table II. WOOD CAGED OUTDOORS.

| Species of insects reared from 4 logs 3 ft. long, average diameter 6½ in. Total approximate surface 20 sq. ft. | Number Reared | | Emergence Dates | | Average no. beetles per sq. ft. of bark surface | |
|---|---|---|---|---|---|---|
| | Burned | Not burned | Burned | Not burned | Burned | Not burned |
| Monochamus scutellatus (Say). | 27 | 19 | 5/26/'38 to 8/26/'38. | 5/23/'38 to 8/5/'38. | 1.35 | .95 |
| Pogonocherus mixtus Hald. | 28 | 34 | 5/27/'38 to 6/26/'38. | 5/26/'38 to 6/20/'38. | 1.40 | 1.70 |
| Astylopsis guttata (Say) | 11 | 17 | 6/2/'38 to 8/3/'38. | 6/27/'38 to 7/23/'38. | .55 | .85 |
| Asemum moestum Hald. | 0 | 0 | - | - | 0.0 | 0.0 |
| Chrysobothris dentipes Germ. | 3 | 9 | 1/29/'39 to 2/8/'39. | 1/29/'39 to 2/7/'39. | .15 | .45 |
| Total | 69 | 79 | | Average | 3.45 | 3.95 |
| Species of insects reared from 4 limbs 3 ft. long, average diameter 3½ in. Total approximate surface 10 sq. ft. | | | | | | |
| Monochamus scutellatus (Say). | 5 | 8 | 5/21/'38 to 7/2/'38. | 5/19/'38 to 7/5/'38 | .50 | .80 |
| Pogonocherus mixtus Hald. | 9 | 6 | 5/27/'38 to 6/19/'38. | 5/27/'38 to 6/26/'38. | .90 | .60 |
| Astylopsis guttata (Say). | 6 | 7 | 6/2/'38 to 7/29/'38. | - | .60 | .70 |
| Asemum moestum Hald. | 0 | 4 | - | 5/29/'38 to 6/3/'38. | 0 | .40 |
| Chrysobothris dentipes | 5 | 8 | - | - | .50 | 0 |
| Total | 25 | 33 | | Average | 2.50 | 3.30 |

## DISCUSSION AND SUMMARY OF 1937 RESULTS

An examination of the emergence records of the burned and unburned white pine wood does not show that scorched timber is attractive to secondary wood-destroying beetles nor does it show that such material is particularly repellent in most cases.

It was noted that the burning treatment applied to the wood did not kill the bark beetle larvae present at the time. Miller and Patterson (62) say that moderately severe fires or fires that do not burn the bark from the infested trees fail to destroy the bark beetle broods. According to Beal (2) a great many of our forest fires are more spectacular than damaging. He points out that when a fire rages through the highly combustible foliage of living coniferous trees (crown fire) it creates a false impression of tremendous damage. Crown fires seldom damage merchantable timber and it seems reasonable to assume that such fires do not completely destroy infestations of bark beetles.

A more complete examination of the infested wood of this experiment revealed the white-spotted sawyer, Monochamus scutellatus (Say) as being chiefly responsible for most of the damage. Practically all of the individuals of this species completed their development in one year under East Lansing conditions. In all infested material the gaping larval tunnels of this destructive sawyer were extended into the heartwood. The tunnels of Asemum moestum Hald. also reached the heartwood but the scarcity of this species lessens its importance.

Chrysobothris dentipes Germ., Astylopsis guttata (Say), and Pogonocherus mixtus Hald. might prove beneficial in that they seriously compete with bark beetles for the vital phloem region food of the tree. Their larval work is confined mostly to the inner bark and outer sapwood and it does not seem that they contribute much toward the deterioration of timber. A more detailed discussion of Monochamus scutellatus (Say) as well as other species will be included later.

## MATERIAL COLLECTED IN 1938

On November 6-7, 1938 infested coniferous wood from Hale, Luzerne, Roscommon, Grayling and Whittemore was transported by truck from these northern Michigan localities to East Lansing, cut into appropriate lengths, caged and labeled. A sample lot of infested wood from each tree species for the various localities was caged indoors with the remainder being caged in the open. A description of the type of infested material follows:

**HALE, IOSCO COUNTY:** A quantity of fire-killed jack pine (Pinus banksiana) was obtained from this area. The fire occurred in the fall of 1936 and burned over several sections of timber composed almost exclusively of jack pine. The majority of the trees in this locality had been rather lightly infested during the previous season but had not been attractive for oviposition during the summer of 1938 because of the dry condition of the wood and the fact that much of the bark had become loosened from the trees. The occurrence of this fire in the fall made the

timber originally less susceptible to borer attack the following spring, because sufficient time for rather thorough dessication of the wood had elapsed.

WHITTEMORE, IOSCO COUNTY: A quantity of infested tamarack (Larix laricina) and balsam fir (Abies balsamea) killed by a small road-fire was available here. In addition a few borer-infested pieces of balsam and tamarack cut during the preceding spring but not damaged by the fire was also obtained.

GRAYLING, CRAWFORD COUNTY: Several samples of heavily infested balsam fir and jack pine was cut from storm-felled trees in this locality. From all appearances these trees were killed during the previous late winter or early spring. It was considered worth while to bring material such as this in for study because of the possibility of making comparison between the number and species of insects infesting storm-killed and fire-killed timber.

LUZERNE, OSCODA COUNTY: Storm-felled balsam fir and jack pine, all in the Huron National Forest, were found to be heavily infested with borers. Several sections from various parts of these trees were obtained.

ROSCOMMON, ROSCOMMON COUNTY: It was in this locality that the best material for 1938 study was obtained. A considerable area had been cut over during the previous winter and all slash was left in the clearing. A small fire occurring in the early summer destroyed some of the slash and killed a few of the surrounding white pine, jack pine and Norway pine trees. All burned trees and slash were heavily borer infested. Piles of sawdust pushed out of the burrows by the wood-boring larvae were conspic-

uous everywhere. A considerable amount of the infested slash and fire-killed timber of each tree species was brought to East Lansing. All material from the above localities except that from Roscommon was caged for but one year, at end of which time each piece of wood was carefully examined for wood-boring larvae by splitting. The pine from Roscommon was kept caged for two years.

The following few pages are devoted to a tabulation of the number and kind of wood-boring beetles reared from the described material from each locality as well as other information that it was considered worth while to include. The only emergence dates of indoor reared insects included here are concerned with the Roscommon material.

Table III

HALE, MICHIGAN

Host - Fire-killed jack pine (Pinus banksiana)

Total approximate area bark surface collected - 63 sq. ft.

Approximate date of fire - Fall of 1936

Date wood collected - November 6, 1938

| Species Reared | Number Reared | Emergence Dates |
|---|---|---|
| Monochamus scutellatus (Say) | 3 | June 19-July 2, 1939 |
| Monochamus titillator (Fab.) | 5 | June 6-July 13, 1939 |

This material was split and examined during November, 1939. No larvae of any kind were found.

It is quite probable that the eggs from which the reared beetles developed were deposited in the summer of 1937 and owing

to the dessicated condition of the wood required two years in which to complete their life cycle. The development of Cerambycid beetles in very dry wood is often retarded and some species have been known to spend twenty years in immature stages under such conditions. (3), (15).

Table IV

LUZERNE AND GRAYLING, MICHIGAN

Hosts - Storm-felled balsam fir (Abies balsamea) and jack pine (Pinus banksiana)

Total approximate area bark surface collected:

Balsam fir - 47 sq. ft.

Jack pine - 50 sq. ft.

Approximate date of felling - Spring of 1938

Date wood collected - November 7, 1938

| Species Reared | Number Reared | Emergence Dates |
|---|---|---|
| Balsam fir | | |
| Monochamus scutellatus (Say) | 55 | May 19-June 28, 1939 |
| Jack pine | | |
| Monochamus scutellatus (Say) | 37 | May 22-Aug. 3, 1939 |

When the jack pine was split and examined in November, 1939, three Cerambycid larvae (probably M. scutellatus) and five Buprestid larvae (probably Chrysobothris sp.) were cut from the wood. A similar examination of the balsam fir revealed four sawyer larvae (probably M. scutellatus).

Table V

WHITTEMORE, MICHIGAN

Hosts - Fire-killed larch (Larix laricina)

Unburned larch

Fire-killed balsam fir (Abies balsamea)

Unburned balsam fir

Total approximate area of bark surface collected:

Fire-killed larch - 30 sq. ft.

Unburned larch - 30 sq. ft.

Fire-killed balsam fir - 40 sq. ft.

Unburned balsam fir-40 sq. ft.

Approximate date of burning and felling - Spring of 1938

Date wood collected - November 6, 1938

| Species Reared | Number Reared | Emergence Dates |
|---|---|---|
| (Fire-killed larch) | | |
| Monochamus scutellatus (Say) | 11 | May 26-June 19, 1939 |
| (Unburned larch) | | |
| Monochamus scutellatus (Say) | 14 | May 26-June 13, 1939 |
| Melanophila plagifera Oben. | 9 | May 20-June 2, 1939 |
| (Fire-killed balsam fir) | | |
| Monochamus scutellatus (Say) | 43 | May 23-June 17, 1939 |
| (Unburned balsam fir) | | |
| Monochamus scutellatus (Say) | 56 | May 18-June 20, 1939 |

An examination of the various woods for immature forms in November, 1939 revealed the following numbers present. All were probably larvae of Monochamus scutellatus (Say):

Larch (burned and unburned) - 5

Balsam fir (burned and unburned) -9

## Table VI

## ROSCOMMON, MICHIGAN

Hosts - Fire-killed white pine, (Pinus strobus), jack pine, (Pinus banksiana) and Norway or red pine, (Pinus resinosa). Branches and tops (slash) from a recent cutting of each of the above tree species.

Total approximate bark surface of each wood collected - Fire-killed - 40 sq. ft., slash - 30 sq. ft.

Approximate time of fire - Spring of 1938

Date wood collected - November 7, 1938

Average diameter fire-killed timber - six inches; slash - four inches.

The following page is devoted to an emergence record for the Roscommon material.

Table VI Showing Number, Species and Emergence Dates of Beetles Reared from Fire-Killed and Slash Native Michigan Pines.

| | Jack Pine Slash | Jack Pine Scorched | Emergence Dates | White Pine Slash | White Pine Scorched | Emergence Dates | Red Pine Slash | Red Pine Scorched | Emergence Dates |
|---|---|---|---|---|---|---|---|---|---|
| Monochamus scutellatus (Say). | 27 | 43 | 5/18/'39-7/23/'39. | 39 | 58 | 5/18/'39-7/30/'39. | 13 | 28 | 5/21/'39-7/16/'39. |
| Monochamus titillator (Fab.). | 15 | 3 | 6/16/'39-7/24/'39. | 19 | 4 | 6/18/'39-7/26/'39. | 2 | 3 | 6/18/'39-6/24/'39. |
| Monochamus notatus (Drury). | | | | | 2 | 1/7/'40. | | | |
| Acanthocinus pusillus (Kby.). | 2 | 3 | 5/28/'39-6/6/'39. | 5 | 11 | 5/24/'39-6/2/'39. | 3 | 4 | 6/2/'39-7/7/'39. |
| Anoplodera canadensis (Fab.). | | | | | 1 | 5/31/'39. | | | |
| Anoplodera vittata (Oliv.). | | | | 1 | 2 | 6/3/'39. | | | |
| Astylopsis guttata (Say). | | | | 5 | 7 | 6/16/'39-6/30/'39. | | | |
| Acmaeops proteus (Kby.). | | | | 6 | 5 | 5/28/'39-6/11/'39. | | | |
| Typocerus velutina (Oliv.). | | 1 | 6/7/'39. | | | | | | |
| Rhagium lineatum Oliv. | | | | 2 | | 6/2/'39. | | | |
| Callidium antennatum Newn. | | | | 1 | 1 | 6/8/'39. | | | |
| Chrysobothris blanchardii Horn. | | | | 6 | 2 | 6/20/'39-2/3/'40. | | | |
| Chrysobothris scabripennis C.&G. | | | | 67 | 5 | 1/26/'40-2/2/'40. | | | |
| Chrysobothris dentipes (Germ.). | 3 | | 1/30/'40. | 5 | 2 | 6/23/'39-2/10/'40. | 3 | 1 | 1/29/'40-2/10/'40. |
| Chalcophora virginiensis Drury. | | | | | 7 | 1/26/'40-2/6/'40. | | | |
| Totals | 47 | 50 | | 156 | 107 | | 21 | 36 | |

## PARASITES AND PREDATORS REARED OR OBSERVED IN ROSCOMMON AREA

Predators - Several specimens of the Clerid, Thanasimus dubius were reared from white and red pine slash which had been infested with bark beetles. This species, commonly known as the American bark beetle destroyer, has been reported by Felt (24 p. 500), Graham (34, p. 350), Doane, Van Dyke, Chamberlin and Burke (20, p. 214) and others as preying on various bark beetles in pines and spruces in the eastern parts of our country.

A large Elatrid larva was cut from a borer infested white pine log in the near vicinity of the Roscommon fire and slashing. This immature click beetle readily devoured larvae of Monochamus scutellatus in the laboratory but unfortunately died before maturing; making a determination to species difficult. It is quite possible that this predator was a member of the genus Alaus Esch. Fiske (26) reports Alaus myops Fab. as being the principal enemy of Monochamus in pines, following its prey to their pupal cells deep in the wood, where it will not only destroy mature larvae and pupae but also attack fully formed and nearly hardened adults. Blatchley (6, p.718) reports this beetle to be common in the southern states but rare north of the Ohio River. Webb (90) says that Monochamus titillator (Fab.) is preyed upon by an Elaterid beetle of the genus Alaus but he probably refers only to the southern states.

Parasites - 33 specimens of an Ichneumon parasite emerged from the cages between May 14, 1939 and June 2, 1939. This parasite, Ichneumon (Ephialtes) mesocentrus (Gravenhorst) (Plate XXVII, fig. 1) is undoubtedly parasitic on Monochamus and probably on its larval stages as all cocoons of the parasite were found in larval tunnels and none in the pupal chambers. (Plate XXVII, fig. 2). But one

parasite of this species was reared from Pinus resinosa (red pine) which may have been due to the lighter infestation of this wood by Monochamus, or to the fact that its thicker scaly bark offers a handicap to oviposition by parasites.

Two specimens of a Braconid parasite and three specimens of a dipterous flesh-fly, family Sarcophagidae emerged from white pine fire-scorched wood during late May, 1939. The puparia of the Sarcophagids were located close to the surface in a larval tunnel of Monochamus but certainty as to their host, as well as that of the Braconids was impossible to establish.

Mites - Several specimens of adult Monochamus scutellatus (Say) and M. titillator (Fab.) from the Roscommon area were found to be heavily infested with mites about the head and thorax. (Plate XI, fig. 2). Infested beetles appeared annoyed as they would repeatedly attempt to dislodge their tormentors by means of their front legs. From all appearances, mite-infested beetles are not vitally injured as they were observed both in copulation and oviposition. The presence of mites does not seem to have any effect on the adult life-span; in one breeding cage a mite-infested female outlived nine other mite-free individuals. In all observed cases the beetles were already infested with mites when they emerged from the wood and it seems fairly certain that the infestation takes place within the wood, possibly in the pupal stage. Mite infested beetles do not seem to spread the infestation even though they come in close contact with mite-free individuals; this can be better understood when one tries to remove the parasites, especially from the thorax, where they cling to the pubescence with such tenacity that it is only with consider-

able difficulty that they can be removed.

## DISCUSSION AND SUMMARY OF 1938 RESULTS

During this year advantage was taken of an opportunity to make comparative studies of the secondary wood-boring beetle infestations in slash, storm-felled and fire-killed coniferous timber. While emphasis in this study is directed toward fire-killed trees mostly, attention to slash or storm-felled timber, especially in close proximity to burned-over areas was considered worth while.

Over the entire area concerned it was observed that the bulk of the damage could be charged to the white-spotted sawyer, Monochamus scutellatus (Say). Craighead and Middleton (18), Pierson (66), and Hopping (47), report the sawyer, Monochamus marmorator Kby. as attacking dead and dying balsam fir in the northeastern states and Canada. No adults of this species were reared from balsam fir during the entire time that this work has been carried on.

Results of this year's work do not indicate that fire-killed timber has any particular attraction for wood-boring insects found in Michigan. An examination of the emergence records show that from a total of approximately 190 sq. ft. bark-surface of scorched timber, which did not include the unattractive material at Hale, 250 specimens of beetles were reared making an average of 1.31 insects per sq. ft.; from a bark-surface total of 257 sq. ft. of storm-killed and slash coniferous wood, 394 specimens of beetles were reared or an average of 1.53 insects per sq. ft.

With reference to the Roscommon area where conditions for secondary wood-destroying insects were especially favorable, it was noted that Buprestid beetles of the genus Chrysobothris Esch. are especially adapted for breeding in slash. These insects invariably were more numerous in the thinner barked branches than in the thicker barked trunk regions. Chrysobothris scabripennis C. & G. was found to be the commonest Buprestid present but was reared only from white pine. Chrysobothris dentipes (Germ.) reported by Blackman and Stage (3) as breeding "in immense numbers" in pine slash and a closely related species Chrysobothris blanchardii Horn, were present in modest numbers. The large Buprestid, Chalcophora virginiensis Drury (Plate XXVI, fig. 2) reported by Buttrick (9) as being chiefly responsible for the deterioration of fire-killed timber in the Black Hills of South Dakota is apparently not of much importance in similar situations in Michigan. Only seven specimens of this species have been reared in Michigan during this study and these from white pine near Roscommon.

It was noted in the Roscommon area that fire-injured trees were attacked by bark beetles, especially ambrosia beetles of the genus Gnathotrichus Eich. (5), (51), (73), (75). All of the injured trees in the locality were salvaged the first winter after the fire making further observations impossible. Some of these trees had severe foliage and cambium injury as a result of the fire, which together with bark beetle attack, would have made their death practically certain (72).

Observations in the forest area surrounding the Roscommon

slashing and burning made during the summer of 1939 did not indicate any menace to the healthy trees as a result of the ideal breeding conditions afforded by the slash and fire-killed trees. No healthy trees in the immediate vicinity were found to be infested by bark beetles. Patterson (64) says that in the West, slash is particularly attractive to the bark beetle, Dendroctonus brevicornis Lec., but these infestations are not a menace to neighboring timber. He states that such conditions cause a temporary concentration in the slash but the infestation returns to normal within a year. Craighead (17) and Graham (30) believe that but few species are capable of adapting themselves to breeding in slash and killing living trees. They realize that at times outbreaks of slash-breeding insects might kill mature trees but state that these outbreaks are sporadic and believe that but little benefit could be derived from disposing of slash. Dunn (23) considers secondary forest insects, which by their activities hasten the process of decay and the resulting reduction of the wood to humus, are almost entirely beneficial within the forest itself. He agrees, however, that such insects may cause serious losses to the timber industry.

An examination of the Roscommon emergence table (Table VI) indicates that white pine is a most pronounced favorite for secondary wood-destroying insects. This seems true in spite of the fact that this material, owing to its thin, dark-colored, heat-absorbing bark, easily reaches temperatures fatal to many larvae in the top surface of logs exposed to direct sunlight. Graham (28), (29), (31), (32) has found that the thick, scaly, light-colored bark of Norway pine offers more protection to wood-boring

larvae than the bark of white pine.

From approximately 70 sq. ft. bark surface of Norway pine from Roscommon, 57 beetles comprising four species were reared; from a corresponding amount of white pine, 262 beetles and twelve species were reared, while jack pine yielded 97 beetles and five species.

Considering the above facts, it seems reasonable to assume that white pine is more attractive to secondary wood-destroying insects than are other pines in Michigan. Craighead (13) says that certain species of Cerambycidae breeding in a variety of hosts, often show a preference for a few of these. Monochamus scutellatus (Say), while breeding in the pines, spruces, fir and tamarack of Michigan seems to exhibit a most pronounced attraction for white pine (31).

## 1939 MATERIAL

### PRESQUE ISLE FIRE

From 9:00 A.M. on Saturday, May 6, 1939, to the following Monday at noon, May 8, 1939, an uncontrolled forest fire raged in northern Montmorency county about eleven miles south of Onaway, Michigan. According to estimates by the Michigan Department of Conservation a total of 28,556 acres of forest land was burned over, of which 18,956 acres was State owned and 9,600 acres privately owned land. Conservation field reports further classify the fire as follows:

Surface-fire-13,798 acres; crown-fire-14,757 acres and ground-fire-one acre. A Michigan Department of Conservation summary of the estimated damage to forest land and timber follows:

| | | |
|---|---|---|
| 1. | Merchantable timber (6-9 inch diameter class and above) | $62,848.00 |
| 2. | Reproduction (Below 6-9 inch diameter class) | 96,649.81 |
| 3. | Denuded Forest Land at $1.00 per acre | 3,850.00 |
| | Total | $163,347.81 |

The dominant tree species in the burned-over area included jack pine, white pine, Norway pine, oak, white birch, aspen, and swamp timber (balsam fir, spruce and tamarack). Jack pine was the dominant single tree species considering the area as a whole. Over 2500 acres of jack pine in 6-12 inch diameter class was destroyed.

The fire was aided in its headway by a 19 to 30 M.P.H. wind which was highly favorable for a crown fire. Practically all of the smaller trees in the area were killed outright either through complete destruction of the foliage or by severe cambium injury. A majority of the taller Norway and white pine trees escaped with only partial or no foliage injury and as a result were not killed at the time of the fire. Salvage operations on this fire-injured as well as fire-killed large timber was begun immediately, leaving but little opportunity to study it. This fire occurred at a time of year such as to make the affected timber highly susceptible to borer attack. (9), (45), (87). Since the fire occurred on May 6-8, 1939 and sawyer beetles were observed as early as May 18, 1939, sufficient time for the wood to dry out to such an extent as to make it unattractive for oviposition had not elapsed.

On October 4, 1939 samples of infested jack pine (Pinus banksiana), white pine (Pinus strobus), Norway or red pine, (Pinus resinosa), balsam fir (Abies balsamea), and black spruce (Picea mariana) were cut from this area and transported by truck to the laboratory at East Lansing for winter study. The extent to which the standing trees were damaged could be somewhat accurately gauged by the large piles of sawdust around each infested tree. The samples were chosen at random over the entire burned area and were cut largely from the trunk and larger branches. It was noted that in this area small fire-killed trees of 3 inch diameter or less as well as the smaller branches of the larger trees were almost totally free from borers. In addition to the above samples two small infested trees each of white pine, jack pine, Norway pine, and balsam fir were cut, trimmed and brought to the laboratory intact for tree species and infestation comparisons. To supplement this, larval counts were made in the Presque Isle fire locality by splitting varying amounts of wood from several different infested tree species.

All wood samples from this fire were caged indoors on November 11, 1939 and cared for in a manner already described.

## 1939 RESULTS

The following tables show species reared and the extent of infestations for the various wood caged. Table VII shows the number and species of beetles reared from various types of coniferous timber killed by the Presque Isle fire.

TABLE VII SHOWING NUMBER AND SPECIES OF BEETLES REARED FROM PRESQUE ISLE FIRE-KILLED TIMBER. (TRUNKS AND LARGER BRANCHES CHOSEN AT RANDOM OVER WHOLE AREA.)

| | Jack Pine (P. banksiana) | White Pine (P. strobus) | Norway Pine (P. resinosa) | Balsam fir (A. balsamea) | Black Spruce (P. mariana) | |
|---|---|---|---|---|---|---|
| Number square feet of bark surface collected. | 100 | 50 | 50 | 25 | 100 | |
| Species Reared. | | | | | | Emergence Dates. |
| Monochamus scutellatus (Say) | 63 | 38 | 11 | 13 | 23 | Dec. 2, 1939 to March 11, 1940. |
| Acanthocinus pusillus (Kby.) | 5 | 9 | 1 | | 14 | Dec. 27, 1939 to Feb. 23, 1940. |
| Astylopsis guttata (Say) | | 7 | | | | Feb. 3, 1940 to Feb. 26, 1940. |

Table VIII shows the extent to which the various woods were infested with the larvae of Monochamus scutellatus (Say). A six-foot section was removed from the lower trunk region of the largest trees obtainable in each tree species. After the average diameter was determined, the larvae were chopped from the wood and counted on October 4, 1939.

Table VIII

| Tree Species | Approximate no. cubic ft. examined. | Total no. of larvae. | Average no. of larvae per cubic foot. |
|---|---|---|---|
| White Pine | 10 | 93 | 9.3 |
| Norway (red) Pine | 10 | 44 | 4.4 |
| Jack Pine | 20 | 176 | 8.3 |
| Balsam Fir | 10 | 87 | 8.7 |
| Black Spruce | 10 | 72 | 7.2 |

Table IX shows the number of adults of Monochamus scutellatus (Say) reared from two entire trees of approximately the same size of four different species in the Presque Isle fire area. These trees were chosen from within an area of about ten acres and averaged about 20 feet in height and about 5 inches in diameter at the base. It was unnecess-

ary to cage the smaller branches as they were generally not infested with sawyer larvae.

Table IX

| Tree Species | No. sawyer adults reared from tree no. 1. | No. sawyer adults reared from tree no. 2. | Total reared from both trees. | Average no. adults reared per tree. |
|---|---|---|---|---|
| White Pine | 28 | 41 | 69 | 34.5 |
| Norway Pine | 11 | 16 | 27 | 13.5 |
| Jack Pine | 31 | 23 | 54 | 27.0 |
| Balsam Fir | 17 | 23 | 40 | 20.0 |

## DISCUSSION AND SUMMARY OF 1939 RESULTS

As a result of observations for a period of one year it appears that practically all of the damage to timber in the Presque Isle fire region was done by the sawyer Monochamus scutellatus (Say). No other species of Monochamus has been reared as yet from this locality. The Cerambycids, Acanthocinus pusillus (Kby.) and Astylopsis guttata (Say), so commonly associated with Monochamus in pines (15, pp. 116-119), are almost exclusively bark feeders, rarely entering even the sapwood, and thus cannot be considered of any importance in timber deterioration.

PARASITES AND PREDATORS. The importance of parasites and predators in the Presque Isle burned-over area seemed to be slight. Woodpeckers were quite numerous during the early fall months. They undoubtedly destroyed many larvae especially in the smaller trees where their prey must necessarily be closer to the surface. Woodpecker work was found to be quite common throughout the burned area and might possibly be considered of some importance in the control of wood-boring insects in such situations. (1), (20, p. 23), (30), (33). Hopkins (44), Buttrick (9) and Graham (34, p. 358) consider woodpeckers to be a factor in keeping small infestations of forest insects from becoming epidemic because of their great powers of mobility enabling them to concentrate on such spots rapidly, but they do not believe birds can be much of a factor in large areas of dead trees such as the Presque Isle fire area. Strickland (82) believes that the reproductive rate and territorial limitations of birds prevents their playing an important part in insect control.

A number of Clerid larvae were observed under the bark of bark beetle-infested wood, but the Clerids are usually considered to be predators of bark feeding forms such as Dendroctonus spp. or Acanthocinus spp. (15, p. 119).

Very few parasitic insects were reared from caged wood or observed in the fire locality. Several Hymenopterous parasites of the family Braconidae emerged from Norway pine cages. Some of the pupal cases of these insects were found to be in the larval tunnels of Monochamus scutellatus (Say) indicating that

they might be parasitic on the latter species. (19).

Two undetermined Diptera, family Tachinidae, were reared from a cage containing white pine. Considering the habits of this family and the fact that the puparia were found in a heartwood larval tunnel of Monochamus scutellatus (Say) (Plate XXVIII) it might not be unreasonable to assume the latter insect to be their host, although Tachinid flies do not appear to be adapted for ovipositing in, on, or near protected larvae such as Monochamus.

During late August, 1939 several parasites of the family Ichneumonidae, genus Rhyssa, were captured. These large insects were flying around borer-infested trees, although none were observed in the process of egg-laying. Species of Rhyssa are generally considered to be parasitic only on Siricid wood wasps (35). Merrill (61) claims Rhyssa to be primary parasites of Monochamus but Rohwer (70, p. 418) believes records of these insects parasitizing Monochamus are open to question. While no Siricid larvae or adults were found in the fire area, proof of Rhyssa sp. parasitizing Monochamus is lacking as far as this investigation is concerned.

## MONOCHAMUS SCUTELLATUS (SAY) AND HOST SELECTION

Tables VIII and IX show sawyer larval infestation and number of adults reared from dead wood of various tree species.

The counts made indicate a preference by Monochamus scutellatus (Say) for white pine over all other tree species examined. A definite preference is apparently exhibited by

the white-spotted sawyer for white pine, jack pine, spruce and fir over Norway (red) pine. If a stand of white and Norway pine were to be salvaged after a spring fire, it would seem advisable to remove the white pine first. Hopkins (43), Graham (31) and others have reported white pine as especially liable to damage by sawyers and other borers.

RELATION BETWEEN SECONDARY BORERS AND FUNGI INFECTION OF FIRE-KILLED TIMBER. Stickel and Marco (81), Beal (2), and others have emphasized the importance of fungi in the deterioration of fire-killed timber. This activity by fungi begins almost as soon as the tree dies and continues until the wood is reduced to a crumbling mass of humus.

Rumbold (71) and Hubert (52) among others have investigated the "blue stain" or "blue rot" caused by Ceratostomella sp. in timber. Rumbold (71) reports two species of Ceratostomella to be definitely associated with Dendroctonus and Ips bark beetles while Snyder (75), Buttrick (9), Leach, Orr and Christenson (57) and others have associated the ambrosia beetles with stained timber.

A number of wood specimens brought from the Presque Isle area showed fungi staining in the sapwood but no attempt was made to identify the causal organisms.

Boyce (7) says that wood destroying fungi cannot penetrate the bark or living sapwood but must have direct access to the heartwood in order to completely infect a tree. The larval tunnels of Monochamus sp, pave an ideal way for wood-rotting fungi to the heartwood of coniferous timber. Leach, Orr and

Christenson (58) found a fair degree of correlation between the number of Monochamus beetles present in the logs and the amount of heart-wood decay. They found the fungous Peniophora gigantea to be primarily responsible for almost complete decay of Norway pine logs three years after cutting. They believe Buprestid beetles to have little influence in the spread of wood-rotting fungi because of the closed larval tunnels of these insects.

An examination of wood samples from the Presque Isle fire revealed heartwood decay only in those cases where the tunnels of Monochamus scutellatus (Say) had reached this region of the wood. (Plate XIV). While wood-rotting fungi might eventually reach the heartwood regions due to deterioration of the sapwood, sawyer tunnels facilitate and speed up the process. (34, p. 261).

Fungi-infested wood was placed in proper growing conditions in order to obtain reproductive spores of the fungous. Professor Forrest Strong, Forest Pathologist at Michigan State College, examined the cultures and identified the fungous as Peniophora sp.

EFFECT OF THE SEASON OF PRESQUE ISLE FIRE. Buttrick (9) states that the optimum conditions for attack by wood-boring insects seems to be following fires which occur early in the growing season. He says that at such times, the killing power of the fire is at its maximum. The moist condition of the wood causes fermentation accompanied by a rise of temperature which is favorable to the rapid development of the larvae, giving them time to become thoroughly established before subsequent dry, hot weather causes seasoning of the wood. Buttrick (9) gives a

comparison of the infestation following two fires occurring at different times in South Dakota. "On one large area burned about the middle of June, the infestation by the last of August was so severe that the ground under the trees was white with the dust from the borings, which could be seen drifting to the ground like a light snow. The gnawing of the larvae sounded like the croaking of innumerable frogs. An area close by burned in March was much less severely infested."

The conditions in the Presque Isle fire region was not much unlike those described by Buttrick (9). Piles of boring dust surrounded almost every tree and the ambitious rasping of the larvae could be heard as late as October 4th. The presence of sawyer adults soon after occurrence of this fire gave an ominous warning as to what destruction would follow.

## DISCUSSION OF SPECIES OF WOOD-BORING COLEOPTERA REARED FROM DEAD CONIFEROUS TIMBER IN MICHIGAN

Doubtful specimens whose identification could not be accurately made by comparisons with species in the Michigan State College Entomological Collection were kindly determined by Doctor Josef Knull, Coleopterist at Ohio State University, Columbus, Ohio.

### Cerambycidae

### *Monochamus scutellatus* (Say)

### (*Monochamus scutellatus* (Say))

The white-spotted sawyer, *Monochamus scutellatus* (Say)

(Plate I), was found to be the commonest insect breeding in dead coniferous timber in all areas observed in Michigan. In these localities it has been found to be responsible for at least 95% of the damage. Graham (34, p. 260) says that it is so common in the Northeast that practically every log or freshly killed tree left in the woods over summer is almost sure to be infested.

DISTRIBUTION: Hopping (47) gives the habitat for this species as New England, Canada (except British Columbia) and Alaska. Blackman (16) gives the distribution as throughout Canada and the northern part of the United States from coast to coast as far north as the Hudson Bay and Yukon regions and as far south as New Mexico and West Virginia. It is probable that he was including in this range the far western, closely related species M. oregonensis Lec. Doane, Van Dyke, Chamberlin and Burke (20, p. 187) refer to M. oregonensis Lec. as a subspecies of M. scutellatus (Say)

HOSTS: Hopping (47) gives the hosts as Pinus strobus, P. resinosa, P. banksiana, Picea canadensis, and Abies balsamea. In 1938, American larch, Larix laricina, at Whittemore, Michigan was found to be quite heavily infested with M. scutellatus (Say). Blackman and Stage (3) also reared this species from Larix laricina. Picea mariana, in the Presque Isle fire area was found to be infested with this sawyer in 1939. In view of the above facts it would seem quite logical to assume that the hosts of M. scutellatus (Say) include the pines, spruces, firs, and larches throughout its habitat.

SEASONAL HISTORY: Under normal Michigan conditions the life cycle requires but one year. This may be lengthened to two, three or even four or more years under adverse moisture or light conditions. (34, p. 261) (3, p. 71). About 95% of the beetles reared in outside cages during 1937 and 1938 completed their development in one year. On October 4, 1939 three adult exit holes were observed in a jack pine tree killed by the Presque Isle fire on May 6, 1939. A section of the trunk of this tree was removed for larval counts, and in the process, two pupae were found along with a dozen or more larvae. The above facts indicate that in some cases the life cycle is completed in less than six months. It seems improbable that oviposition had occurred in this tree earlier than May 6, 1939. Conditions in the Presque Isle area were ideal for rapid development due to an almost complete lack of shade and the warm, late autumn season of 1939.

Adults of the white-spotted sawyer are at large from about the middle of May to September and eggs may be deposited at any time between those dates although the bulk of egg-laying probably occurs before the last of July.

In depositing her eggs the female commonly chooses a spot near the juncture of a branch with the trunk or twig with a limb. She cuts a slit (usually transverse) in the bark with her sharp mandibles, turns promptly around and deposits her egg. In observing oviposition in the laboratory, the female, after cutting the slit in the bark, appeared to pry it up with her ovipositor, after which the egg was inserted as far as possible under the slit and into the green inner bark.

In all observed cases single eggs were laid. Blackman (3) tells of this species constructing "egg pits" in which several eggs are deposited. A thorough examination of bark in which eggs had been laid in the laboratory revealed deposition only in a manner described above. The maximum observed number of eggs laid by a single female in captivity was five but this is probably less than the usual number deposited. Tragardh (88) states that the minimum number of eggs laid by Monochamus sutor in Sweden is fifty. Attempts were made by the writer to arrive at the number of eggs normally deposited by sawyers in the following manner. Individual fertilized females were placed in cages together with freshly killed white pine limbs suitable for oviposition until death of the beetle occurred. Subsequent examination of the bark revealed one beetle as depositing five eggs while three others laid only two each.

The egg (Plate III, fig. 2) is snow-white, opaque, elongate-oval and about one-eighth inch long. Eggs placed under what was considered optimum conditions required from seven to twelve days to hatch in the laboratory.

The larvae when first hatched (Plate III, fig. 2) are of course very small with a head which seems large in proportion to the rest of the body. These legless, white "grubs" equipped with powerful mandibles excavate broad shallow galleries in the phloem region but as they increase in size penetrate not only the green inner bark but also the surface of the sapwood. Later the larvae enter the sapwood and eventually the heartwood in most cases. (Plates V, VIII). Entrance into the sapwood is always signified by the oval-shaped holes near

the larval feeding excavation. (Plates IV, VII). The space between the feeding excavations and the outer bark is commonly crowded with tough, excelsior-like shreds of wood. Larvae hatching in late June up to mid-July usually have entered the sapwood by the first week in September. As the larval tunnels penetrate the sapwood toward the heartwood they increase in size to accommodate the growing larvae. Some of these gaping holes in the sapwood and heartwood measure a half inch in width. (Plate VIII). During this larval feeding period much boring dust or frass is pushed from the tunnels by the activity within. After entering the heartwood, the tunnels run longitudinally for a short distance and then curves toward the surface making a U-shaped gallery. The larvae apparently always strive to move toward light. Stark (80) has found that the larvae of Monochamus change the direction of their course if logs are turned so as always to move toward light.

Larval activity usually ceases in Michigan by about October 15, the winter, as a rule, being passed in this stage. December and January examinations of infested wood showed most of the larvae to be in the heartwood. Feeding activity by the larvae is resumed during April in Michigan; this, of course, depending on prevailing temperatures. Full-grown larvae often measure one and one-half inches or more in length. (Plate VI).

Before pupation, the larval tunnel is extended out of the heartwood toward the surface to within a fraction of an inch from the inner bark. This will later serve as an exit for the adult when it transforms. The larval entrance to the pupal chamber is tightly plugged with excelsior-like frass and the

larva retires to the deeper, and more spacious part of the burrow to pupate. (Plates IX, X). Larvae going through the winter in the most advanced stage are of course the first to pupate in the spring. Pupation in Michigan may begin as early as the first week in May and continues through the early summer until August. Observations made in the laboratory indicate that from eight to sixteen days are required for the pupal period, with the average around twelve days.

After transformation, the adult cuts its way to freedom by making use of its sharp mandibles and emerges through a clean-cut, nearly circular exit hole (Plates XI, fig. 1; XII, XIII). Adults in Michigan have been observed to emerge as early as May 13, but under normal conditions the peak of emergence occurs in June.

The adult insects are attractive, somewhat elongate, cylindrical, black beetles more or less mottled with white. (Plate I). The scutellum is invariably clothed with a heavy white pubescence, hence the specific name, scutellatus. The antennae are very long and filiform, giving the insect a terrifying appearance to those not familiar with it. The male antennae are twice or more times the length of the body while those of the female are only slightly longer than the body. Size variations are quite pronounced in this species; some beetles being more than one inch long, while others are less than a half-inch in length. (Plate II, figs. 1 and 2). The color varies from pure black (except the scutellum) in some individuals to those having the wing covers heavily mottled with a white pubescence. (Plate III, fig. 1).

The adults of the white-spotted sawyer feed rather voraciously in captivity. Fresh white pine shoots were stripped of bark and needles by their feeding activity when introduced into breeding cages. (Plate XV). Blackman (3) reports feeding on coniferous twigs by adult beetles and Pierson (67) says feeding by Monochamus on underside of coniferous twigs causes them to die, the injury later showing up as red or brown needles. Craighead (15, p. 106) reports feeding by adults on conifer needles to be extensive and that on spruce trees near logging operations sufficient branches are sometimes killed as to cause serious defoliation and malformation.

Adults kept under favorable conditions in the laboratory, lived on the average about two weeks. Blackman (3) reported one beetle as living 31 days but this was probably an exceptional case.

CONTROL MEASURES ADVOCATED: Various methods have been recommended for reducing sawyer injury to merchantable timber. Where possible, prompt utilization of felled or fire-killed timber is the best way to handle the problem. If this is impossible, other methods may be resorted to, each of which has its disadvantages. Water storage (34, p. 262), (83), (21), (22) is said to prevent damage if ponds or rivers are situated near enough to the logging region to make this practice convenient. However, Rodd (69) says that larvae in floating trees often survive as long as three months, the only consequence being a delay in their development.

The removal of bark from logs will prevent egg-laying by

sawyers but this would be useless if the larvae had already penetrated into the wood. Barking is an expensive process, making such operations on low grade, knotty logs unadvisable. Barking saw logs has one objection in that it causes checking. This is brought about by the more rapid drying and shrinking of the outer portions than the inner parts. Graham (34, p. 123), Dunn (22), and Swaine (83) (86) have found the use of lime sulphur dust on logs to be effective and have also recommended the covering of log piles with spruce or balsam boughs. The use of insecticides and bough coverings does not insure complete protection against sawyers, and should be resorted to only when it is impossible to employ other methods.

Monochamus titillator (Fab.)
(Monochamus titillator (Fab.))
(Lamia titillator (Fab.))

Hopping (47) considers carolinensis Oliv.; minor Lec.; and dentator Fab. to be synonyms of titillator.

The southern-pine sawyer, Monochamus titillator (Fab.) (Plate XVI) has been reported by Webb (89) (90) (91), St. George and Beal (78), Craighead and Middleton (18), Craighead (15, p. 106) and others as being very destructive to storm-felled timber in the southern states. This species does not seem to be sufficiently widespread or numerous in Michigan to be of much economic importance. A number of these beetles were reared from pine slash near Roscommon but it is a significant fact that they seemed to be completely absent from the Presque Isle fire area.

HOSTS: Hopping (46) gives the hosts of this sawyer as

Pinus palustris, P. strobus and probable all pines in its habitat as well as Abies balsamea. This insect was reared only from pines in Michigan.

DISTRIBUTION: The southern pine sawyer is said to be found throughout eastern North America, extending west to Alabama in the south and possibly to British Columbia and Alaska.

SEASONAL HISTORY: The discussion of the white-spotted sawyer can be applied very closely to the southern pine sawyer in Michigan, there being but little, if any, variation in the habits, life cycle and injury of the two species.

Monochamus notatus (Drury)
(Monochamus confusor (Kby.)
(Monochamus confusor (Kby.)

The grey sawyer, Monochamus notatus (Drury) (Plate XVII) did not appear to be of any importance in the localities under observation in Michigan, although Dunn (21), (22) and Swaine (84) consider it as a most important secondary insect in the coniferous forests of eastern Canada, being absent only from a small section of the north shore of the Gaspe Peninsula, Quebec. They report this species along with the white-spotted sawyer as following forest fires and completely destroying large areas of fire-damaged trees. Herrick (36, p. 417) has found the grey sawyer attacking living trees and Lang (56) reported an individual of this species as boring through a lead pipe 2½ inches thick.

HOSTS: Hopping (47) lists the hosts as Pinus strobus, P. banksiana, P. resinosa, P. ponderosa, and Picea canadensis.

During the course of this study the grey sawyer was reared only from white pine. (P. strobus).

**DISTRIBUTION:** According to Hopping (47) the range of this insect is the northeastern part of the United States and Canada including British Columbia.

**SEASONAL HISTORY:** From white pine, in which eggs were deposited during the summer of 1938, two adults emerged January 7, 1940. The wood was brought indoors during November, 1939, after being in outdoor cages since the time of collection in the fall of 1938. This indicates a two-year life cycle for these individuals at least. Dunn (22) reports a developmental period of one year in eastern Canada if the summer is unusually warm but states that two years is the normal life-cycle period.

The type of injury and habits of this species are similar to other sawyers already discussed.

Acanthocinus pusillus (Kby.) (Plate XVII, fig. 1). The synonomy of this species is quite confusing. Apparently references to Graphisurus pusillus (Kby.) (38) and Ceratographis pusillus (Kby.). (40) both pertain to the same insect, Acanthocinus pusillus (Kby.).

**HOSTS AND DISTRIBUTION:** This beetle has been variously reported as feeding on the dead inner bark of pines and spruces in northeastern United States. Leng (60) lists its distribution as Maine and northern New York. In Michigan this borer was reared from jack pine, white pine, Norway (red) pine and black spruce. As already stated, the larvae mine only in the inner bark where they are not only harmless but also probably

beneficial in that they seriously compete with bark beetles for this desired phloem-region food.

SEASONAL HISTORY: Development is completed in one year, pupation taking place in a peculiar cell constructed just beneath the bark by building up an elliptical barrier of frass. (Plate XIX).

Astylopsis guttata (Say)
(Astylopsis sexguttata (Say))
(Astylopsis commixta (Hald))
(Astylopsis punctata (Hald))
(Leptostylus sexguttatus Say.)
(Leptostylus commixtus Hald.)

Astylopsis guttata (Say) (Plate XVIII, fig. 2) has been reported by Craighead (15, p. 116) as commonly associated with Monochamus and Acanthocinus in pines and spruces throughout eastern United States. Blackman (3) reared it from the tops and limbs of larch (Larix laricina). Leng (60) gives its distribution as Canada, District of Columbia, Wisconsin and Indiana. Adults were reared in Michigan from white pine in each of the three years of study. Blackman (3) found the developmental period to extend over two years. All individuals reared during the course of this study in Michigan required but one year for development. The larvae do not appear to penetrate even the sapwood to a very great extent and thus cannot be considered as particularly injurious. All observed beetles of this species were associated with the white-spotted sawyer, Monochamus scutellatus (Say).

Asemum moestum Hald.

Leng (60) records this beetle (Plate XX, fig. 1) as being distributed from Alaska south to Lake Superior and Florida. Craighead (15) reports it as breeding in Picea, Larix and Abies throughout eastern and Central North America. Packard (65) reported this species as attacking healthy white pine trees, and Hopkins (37) found A. moestum in spruce and yellow pine. According to Blackman (3) it is probable that this borer will be found in a large number of coniferous trees throughout its range. He reared the beetle only in the basal portions of larch trunks and states that A. moestum is one of the primary insects attacking the weakened tree, often attacking trees before they show any visible signs of weakness -- sometimes a full year before the entrance of Dendroctonus spp.

A. moestum was reared from dead white pine near East Lansing, Michigan, adults emerging on May 29 and June 3, 1938.

SEASONAL HISTORY: Development of this species was completed in one year at East Lansing. Blackman (3) reports the life cycle as ordinarily requiring two years and Craighead (15, p. 32) says one or often two years are needed.

The larvae were found to have made extensive borings deep into the heartwood of white pine limbs causing injury very similar to that of Monochamus. It was also observed that this species was reared only from the moist portions of white pine limbs next to the soil. (32).

Pogonocherus mixtus Hald.

This interesting little species (Plate XX, fig. 2) is said to breed in pines and spruces throughout the eastern and west central United States and Canada. Blackman (3) bred this insect from larch and Leng and Hamilton (59) reported it on pear and willow trees.

Adults of this species emerged in considerable numbers from white pine logs and limbs near East Lansing between May 27 and June 26, 1938. It was not reared from any other locality.

SEASONAL HISTORY: The life cycle of all observed individuals at East Lansing required but one year for completion. Blackman (3) reported the life cycle as extending over a period of two years in larch.

The larvae cut irregular grooves in the sapwood which are surprisingly wide and deep for so small a borer. No instances of this borer extending tunnels into the heartwood were observed, pupation taking place in the sapwood close to the bark surface. Accordingly, P. mixtus cannot be considered as particularly damaging in Michigan.

## OTHER SPECIES

Other species of Cerambycidae reared from dead coniferous timber in Michigan are as follows:

Anoplodera (Leptura) canadensis (Fab.) (Plate XXI, fig. 1)

Anoplodera (Leptura) vittata (Oliv.) (Plate XXI, fig. 2)

Aemaeops proteus (Kby.) (Plate XXVI, fig. 1)

Typocerus velutina (Oliv.)

Rhagium lineatum (Oliv.)

Callidium antennatum (Newn.)

The above were either reared in such few numbers or were associated with so many others that detailed observations on their injury and habits were impossible. The developmental period, hosts and emergence dates can be obtained from the emergence tables.

## Buprestidae

### Chrysobothris scabripennis C. & G.

**DISTRIBUTION:** This metallic wood borer (Plate XXII, fig. 1) is distributed over northeastern United States and Canada west to Lake Superior. (11, p. 169),(60).

**HOSTS:** Chamberlin (11) lists the hosts as white pine (Pinus strobus), spruce (Picea sp.) and hemlock (Tsuga canadensis). Considerable numbers of this Buprestid were reared from white pine slash at Roscommon, Michigan where it was commonly associated with Monochamus scutellatus (Say). (Plate XXIII).

**SEASONAL HISTORY:** Two years were required for development under Michigan conditions. All the adults seem to mature and emerge at approximately the same time. Seventy-two specimens of this beetle emerged from indoor cages of white pine limbs between January 26 and February 2, 1940. These cages had been outdoors from the fall of 1938 to November, 1939, at which time they were brought indoors. It is reasonable to assume that the beetles would have emerged in the summer of 1940. The flat-headed larvae of this species (Plate XXII, fig. 2) excavate

broad channels entirely in the inner bark and sapwood, rarely penetrating the heartwood at any stage of their development. (Plate XXIV). Pupal cells are constructed in the sapwood close to the bark (Plate XXV). The larval entry holes into the sapwood are very much flattened while the adult exit holes are broadly oval. (Plate XXIII). The larval tunnels, like those of other Buprestids are tightly packed with a fine boring dust or frass.

This species like a closely related form, Chrysobothris dentipes (Germ.), seems especially well adapted to breeding in thin-barked branches or slash. The larvae of such insects have been found by Graham (31) to be able to withstand the higher temperatures which prevail in the thin-barked portions of trees.

Considering the boring habits of Chrysobothris scabripennis, it must be concluded that this species has very little economic importance.

Two related forms of the same genus which closely resemble C. scabripennis are C. blanchardii Horn. and C. dentipes (Germ.). The former was reared only from white pine while the latter was bred from jack pine and Norway (red) pine as well as from white pine. The habits, life cycles, and injuries of these two species closely resemble those of C. scabripennis.

Chalcophora virginiensis Drury.

This striking beetle (Plate XXVI, fig. 2), one of the largest of the family Buprestidae, was reared only from the basal portion of one fire-scorched white pine tree near Roscommon.

DISTRIBUTION: Chamberlin (11) records the range of this beetle as Ontario, to Florida, west to Louisiana, Iowa, Illinois, and Michigan.

HOSTS: Chamberlin (11) lists the hosts as Pinus strobus, P. rigida, P. echinata, P. taeda, P. palustris, and Taxodium disticum (Bald cypress).

SEASONAL HISTORY: Seven beetles emerged from indoor-caged white pine between January 26 and February 6. 1940, which would indicate a life cycle of two years. Buttrick (9), indicates that development for these beetles may be completed in a single year.

The mature larvae of this species are very large, often measuring 40 to 50 mm. in length. Wood attacked by these larvae soon becomes completely riddled with their long, flat, winding tunnels (8).

Hopkins (39) reported this species to be completely riddling mature white pine timber. According to Buttrick (9), Chalcophora virginiensis or one of its closely related western forms was almost completely responsible for deterioration of coniferous timber after fires in the Black Hills of South

Dakota. This does not seem to be the case in Michigan forest-fire areas, although adults of this species seem to be quite common in the northern counties, especially around saw mills, during late May and throughout June.

## GENERAL CONCLUSIONS AND SUMMARY

1. Fire-killed coniferous timber in Michigan does not appear to have any more attraction to wood-boring Coleoptera than timber killed by other agencies. Scorched trees are readily attacked and damaged but emergence records indicate that slash and storm felled trees are even more heavily infested.

2. Fires occurring during the late spring or early summer months render the scorched timber more susceptible to borer attack than fires occurring at other times.

3. Timber killed by any agency is more attractive to wood-boring Coleoptera during the first year after death of the trees. While certain species prefer wood in a more advanced stage of decay, these are of little importance as far as injury to timber is concerned. Borers such as the sawyers require freshly killed trees and will not as a rule re-infest trees from which they emerge as adults.

4. Examinations of dead timber caused by spring fires revealed very heavy damage to merchantable timber by secondary wood borers. The bulk of this injury was confined to the trunks and larger branches; damage to small trees (three-inch diameter and less) as well as the smaller branches of larger trees was negligible.

5. Rather limited examinations of forest trees surrounding Michigan slashings and burned-over areas indicated that such areas are not a menace to adjacent healthy timber.

6. The concentration of secondary wood-borers in burned over areas is very high, resulting in the death of some fire-injured trees which otherwise might have recovered, but it does not appear that borers attacking dead timber can successfully adapt themselves to breeding in healthy trees to any great extent.

7. The white-spotted sawyer, Monochamus scutellatus (Say), was responsible for nearly all damage to dead coniferous timber observed in Michigan. While other species of wood-boring beetles contribute to the ultimate destruction of the wood, they are not present in large enough numbers to be considered of much importance.

8. A study of the biology of the white-spotted sawyer, Monochamus scutellatus (Say), indicates that under normal conditions in Michigan the developmental period is one year. Individuals developing under adverse moisture or light conditions may require a much longer time.

9. Natural control of wood-boring beetles by parasites and predators did not seem to be of much significance in the areas investigated. Woodpeckers and Hymenopterous parasites of the family Ichneumonidae appeared to be of the most importance.

10. The amount of fungous infection in the heartwood of coniferous timber one or two years after death of the trees, appeared to be definitely correlated with the extend of heartwood boring by Monochamus scutellatus (Say), The fungous most commonly present was Peniophora sp. and was observed only in the heartwood of logs penetrated by sawyer tunnels.

11. Larval counts and adult emergence records of Michigan fire-killed timber indicate white pine (Pinus strobus) as the favorite host for sawyers as well as other wood boring Cerambycidae and Buprestidae. These records show Norway pine (Pinus resinosa) to be much less heavily infested than other coniferous tree species.

## LITERATURE CITED

(1) Beal, F. E. 1911. Food of woodpeckers of the United States. U. S. D. A. Biol. Survey Bul. 37.

(2) Beal, J. A. 1935. Deterioration of fire-killed Douglas fir. Timberman, vol. 37, no. 2, pp. 13-17.

(3) Blackman, M. W. and Stage, H. H. 1918. Notes on insects bred from the bark and wood of the American larch. N. Y. State College Forestry, vol. 18; Tech. publication no. 10; no. 4, pt. 1, 115 pp.

(4) Blackman, M. W. 1919. Notes on forest insects. Psyche, vol. 26, no. 4, pp. 85-96.

(5) Blackman, M. W. 1931. A revisional study of Gnathotrichus. Eich. Jour. Wash. Acad. Sci., vol. 21, pp. 223-236.

(6) Blatchley, W. S. 1910. Coleoptera or beetles known to occur in Indiana. The Nature Publishing Co., Indianapolis. 1385 pp.

(7) Boyce, J. S. 1921. Fire scars and decay. Timberman, vol. 22, no. 7, p. 37.

(8) Burke, H. E. 1909. Injuries to forest trees by flat-headed borers. U. S. Dept. Agr. Yearbook, pp. 399-415.

(9) Buttrick, P. L. 1912. Notes on insect destruction of fire-killed timber in the Black Hills of South Dakota. Jour. Econ. Ent., vol. 5, pp. 456-464.

(10) Casey, T. L. 1909. Studies in the American Buprestidae. Proc. Wash. Acad. Science, vol. 11, pp. 47-178.

(11) Chamberlain, W. J. 1926. Catalogue of the Buprestidae of North America north of Mexico. 289 pp.

(12) Craighead, F. C. 1920. Direct sunlight as a factor in forest insect control. Proc. Ent. Soc. Wash., vol. 22, no. 5 pp. -

(13) Craighead, F. C. 1921. Hopkins host-selection principle as related to certain Cerambycid beetles. Jour. Agr. Research, vol. 22, pp. 189-220.

(14) Craighead, F. C. 1922. Experiments with spray solutions for preventing insect injury to green logs. U. S. Dept. Agr. Bul. no. 1079. 11 pp.

(15) Craighead, F. C. 1923. North American Cerambycid Larvae. Dom. of Canada Dept. of Agr. Tech. Bul. no. 27, ns., 239 pp.

(16) Craighead, F. C. 1925. The Dendroctonus problem. Jour. Forestry, vol. 23, no. 4, pp. 340-354.

(17) Craighead, F. C. 1927. Relation of insects to slash disposal. U. S. Dept. Agr. Dept. Circ. 411.

(18) Craighead, F. C. and Middleton, W. 1930. An annotated list of the important North American forest insects. U. S. Dept. Agr. Misc. Pub. no. 74.

(19) Cushman, R. A. 1926. Some types of parasitism among the ichneumonidae. Proc. Ent. Soc. Wash., vol. 28, pp. 29-51.

(20) Doane, R. W., Van Dyke, E. C., Chamberlain, W. J., Burke, H. W. 1936. Forest insects. McGraw-Hill Book Co., Inc. New York. 463 pp.

(21) Dunn, M. B. 1931. Sawyer beetles in pine and balsam fir. Canada Dept. Agr. Div. For. Insects, sp. circular.

(22) Dunn, M. B. 1931. An investigation of Monchamus beetles and their control. 22nd. Ann. Rep. Quebec Soc. Prot. Plants, pp. 86-88.

(23) Dunn, M. B. 1936. The function of wood-boring insects in the development of the forest. Rep. Ent. Soc. Ont., vol. 66, pp. 8-11.

(24) Felt, E. P. 1906. Insects affecting park and woodland trees. N. Y. State Museum Memoir 8.

(25) Felt, E. P. and Bromley, S. W. 1938. Insect damage to trees as consequence of the New England hurricane. Science, vol. 88, Sup. for Nov. 4, 1938, p. 12.

(26) Fiske, W. F. 1907. Notes on insect enemies of wood-boring Coleoptera. Proc. Ent. Soc. Wash., vol. 9, pp. 23-27.

(27) Garver, R. D. 1939. The national timber stand. Jour. Forestry, vol. 37, pp. 92-96.

(28) Graham, S. A. 1921. Controlling insects in logs by exposure to direct sunlight. Jour. Forestry, vol. 19, pp. 512-514.

(29) Graham, S. A. 1922. Effect of physical factors in ecology of certain insects in logs. 19th. Rep. Minn. State Ent., pp. 22-40.

(30) Graham, S. A. 1922. Some entomological aspects of the slash disposal problem. Jour. Forestry, vol. 20, pp. 437-447.

(31) Graham, S. A. 1924. Temperature as a limiting factor in the life of subcortical insects. Jour. Econ. Ent., vol. 17, pp. 377-383.

(32) Graham, S. A. 1925. The felled tree trunk as an ecological unit. Ecology, vol. 6, pp. 397-411.

(33) Graham, S. A. 1930. Ornithology and forest entomology. Mich. Acad. Sci., Arts and Letters, vol. 11, pp. 389-397.

(34) Graham, S. A. 1939. Principles of forest entomology. McGraw-Hill Book Co., Inc. 410 pp.

(35) Hanson, H. S. 1939. Ecological notes on the Sirex wood wasps and their parasites. Bul. Ent. Res., vol. 30, pt. 1, pp. 26-27.

(36) Herrick, G. W. 1935. Insect enemies of shade trees. Comstock Publishing Co., Ithaca, New York, 417 pp.

(37) Hopkins, A. D. 1889. Report on investigations to determine the cause of unhealthy conditions of the spruce and pine. W. Va. Agr. Exp. Sta. Bul. no. 56, pp. 197-461.

(38) Hopkins, A. D. 1893. Catalogue of West Virginia forest and shade tree insects. W. Va. Agr. Exp. Sta. Bul. no. 32. 82 pp.

(39) Hopkins, A. D. 1898. Buprestid larvae destructive to living white pine timber. U. S. Dept. Agr. Div. of Ent. Bul. no. 17, pp. 47-48.

(40) Hopkins, A. D. 1904. Catalogue of exhibits of insect enemies of forests and forest products. U. S. Dept. Agr. Div. of Ent. Bul. no. 48. 55 pp.

(41) Hopkins, A. D. 1904. Insect injuries to forest products. Yearbook, 1904, pp. 381-398.

(42) Hopkins, A. D. 1909. Insect depredations in North American forests and practical methods of prevention and control. U. S. Dept. Agr. Bur. of Ent. Bul. 58, part 5.

(43) Hopkins, A. D. 1910. Insect injuries to the wood of dying and dead trees. U. S. Dept. Agr. Bur. of Ent. Cir. no. 127.

(44) Hopkins, A. D. 1910. Insects in their relation to the reduction of future supplies of timber and general principles of control. U. S. Dept. Agr. Bur. of Ent. Circ. 129.

(45) Hopkins, A. D. 1912. Damage to the wood of fire-killed Douglas fir and methods of preventing losses in western Washington and Oregon. U. S. Dept. Agr. Bur. of Ent. Circ. 159, 4 pp.

(46) Hopping, R. 1915. The entomological aspects of slash disposal. Soc. Am. Forestry Proc., vol. 10, pp. 183-185.

(47) Hopping, R. 1921. A review of the genus Monochamus Serv. (Cerambycidae, Coleoptera.) Can. Ent., vol. 53, pp. 252-258.

(48) Horn, G. H. 1886. A monograph of the species of Chrysobothris inhabiting the United States. Trans. Am. Ent. Soc., vol. 13, pp. 65-144.

(49) Houser, J. S. 1931. Damage to lumber caused by insects. Ohio Agr. Exp. Sta. Bul. no. 478, pp. 41-46.

(50) Howard, L. O. 1919. Report of Entomologist.

(51) Hubbard, H. G. 1897. The Ambrosia beetles of the United States. U. S. Dept. Agr. Bur. of Ent. Bul. (ns.), no. 7, pp. 9-30.

(52) Hubert, E. E. 1921. Notes on sap stain fungi. Phytopathology, vol. 11, pp. 214-224.

(53) Hyslop, J. A. 1938. Losses occasioned by insects, mites and ticks in United States. Bureau of Ent. Publication.

(54) Jaenicke, A. J. 1921. Relation between fires and insect damage. Timberman, vol. 22, no. 3, pp. 113-116.

(55) Kellogg, R. S. 1909. Timber supply of United States. U. S. Dept. Agr. For. Service Circ. no. 166, p. 6.

(56) Lang, F. 1919. Insects damaging lead. Ent. Monthly Mag., 3rd. series, nos. 60 and 61. pp. 278-279.

(57) Leach, J. G., Orr, L. W., and Christensen, C. 1934. Interrelationships of bark-beetles and blue-staining fungi in felled Norway pine timber. Jour. Agr. Research, vol. 49, pp. 315-341.

(58) Leach, J. G., Orr, L. W., and Christensen, C. 1937. Further studies on the interrelationship of insects and fungi in the deterioration of felled Norway pine logs. Jour. Agr. Res., vol. 55, no. 2, pp. 129-140.

(59) Leng, C. W. and Hamilton, J. 1896. The Lamiinae of North America. Trans. Am. Ent. Soc., vol. 23, pp. 101-178.

(60) Leng, C. W. 1920. Catalogue of the Coleoptera of America north of Mexico. Pub. by John D. Sherman, Mt. Vernon, N. Y. 470 pp.

(61) Merrill, J. H. 1915. On some genera of the pimpline Ichneumonidae. Trans. Am. Ent. Soc., vol. 41, pp. 109-154.

(62) Miller, J. M. and Patterson, J. E. 1927. Preliminary studies on the relation of fire injury to bark beetle attack in western yellow pine. Jour. Agr. Res., vol. 34, pp. 597-613.

(63) Mudinger, F. G. 1924. Apreliminary list of the Buprestidae and Cerambycidae of Cranberry Lake Regions, New York. N. Y. State College For. Tech. Pub. no. 17, part 4, pp. 313-320.

(64) Patterson, J. E. 1927. The relation of highway slash to infestations by the western pine beetles in standing timber. U. S. Dept. Agr. Tech. Bul. no. 3.

(65) Packard, A. S. 1890. U. S. Ent. Com. 5th. Rep., pp. 697-699.

(66) Pierson, H. B. 1923. Insects attacking forest and shade trees. Maine For. Ser. Bul. no. 1, p. 28.

(67) Pierson, H. B. 1927. Manual of forest insects. Maine For. Ser. Bul. no. 5, pp. 105-106.

(68) Prozorov, S. S. 1929. (Burnt areas in pine forests as foci of infection) Trud. Sib. Inst. Sel. - Khoz Lesovod, vol. 12, pt. 3, reprint, 54 pp. 17 figs., 6 graphs, 28 refs. (In Russian).

(69) Rodd, E. 1914. (Multiplication of Monochamus on pines in woods of Altai district). For. Jour., vol. 44, nos. 6-7, pp. 1048-1064.

(70) Rohwer, S. A. 1921. The North American Ichneumon flies of the tribes Labenini, Rhyssini, Xoridini, Odontomerini and Phytodietini. Proc. U. S. Natl. Museum, vol. 57, pp. 405-474.

(71) Rumbold, Caroline. 1931. Two blue-staining fungi associated with bark-beetle infestation of pine. Jour. Agr. Res., vol. 43, pp. 847-873.

(72) Salman, K. A. 1934. Entomological factors affect salvaging of fire injured trees. Jour. of Forestry, vol. 32, no. 9, pp. 1016-1017.

(73) Schedl, K. E. 1931. Morphology of the bark-beetles of the genus Gnathotrichus. Smithsonian Misc. Coll., vol. 82, no. 10.

(74) Show, S. B. and Kotak, E. I. 1925. Fire and the forest. U. S. Dept. Agr. Dept. Circ. 358., pp. 6-7.

(75) Snyder, T. E. 1927. Defects in timber caused by insects. U. S. Dept. Agr. Bul. no. 1490. 46 pp., 45 figs., 51 refs.

(76) Sokanovskii, B. 1929. (On effect of insects in burned over areas). Defenses des Plantes, vol. 5, no. 5-6., pp. 667-668. (In Russian).

(77) St. George, R. A. 1929. Protection of log cabins, rustic work and unseasoned wood from injurious insects. U. S. Dept. Agr., Farmers Bul. no. 1582, 19 pp.

(78) St. George, R. A. and Beal, J. A. 1929. The southern pine beetle, a serious enemy of pines in the south. U. S. Dept. Agr., Farmers Bul. no. 1586, 18 pp., 17 figs., 2 refs.

(79) Stark, V. N. and Ctaph, B. H. 1925. (Importance of forest fires as creating foci of bark-beetles in Briansk government). Defense des Plants, vol. 2, no. 4-5, pp. 205-212. (In Russian).

(80) Stark, N. K. 1926. (Some observations on the life of Longicorns). Defense des Plantes, vol. 3, no. 4-5, pp. 343-349. (In Russian).

(81) Stickel, P. W. and Marco, H. R.
Forest fire damage studies in the northeast. III, Relation between fire injury and fungal infection. Jour. Forestry, vol. 34, no. 4. pp. 420-423.

(82) Strickland, E. H. 1928. Can birds hold injurious insects in check? Sci. Monthly, vol. 26, pp. 48-56.

(83) Swaine, J. M. 1916. Some features of interest in connection with our studies of forest and shade tree insects. Ont. Ent. Soc. Report, no. 47, pp. 96-97.

(84) Swaine, J. M. 1917. The large pine sawyer, Monochamus confusor. Ont. Ent. Soc. Report 471, pp. 96-97.

(85) Swaine, J. M. 1925. The factors determining the distribution of North American bark-beetles. Can. Ent., vol. 58, pp. 261-266.

(86) Swaine, J. M. 1928. Forest entomology and its development in Canada. Pamph. Dept. Agr. Canada, no. 97, 20 pp.

(87) Tothill, J. D. 1923. Injury to fire-killed lumber in New Brunswick by the softwood borer. 63rd. Annual Report Crown Land Dept., New Brunswick, pp. 86-87.

(88) Tragardh, I. 1929. (On the injury caused by the pine sawyer, Monochamus sutor and its prevention). Medd. Skogsforsoksanst, no. 25, pp. 171-288. Sweden.

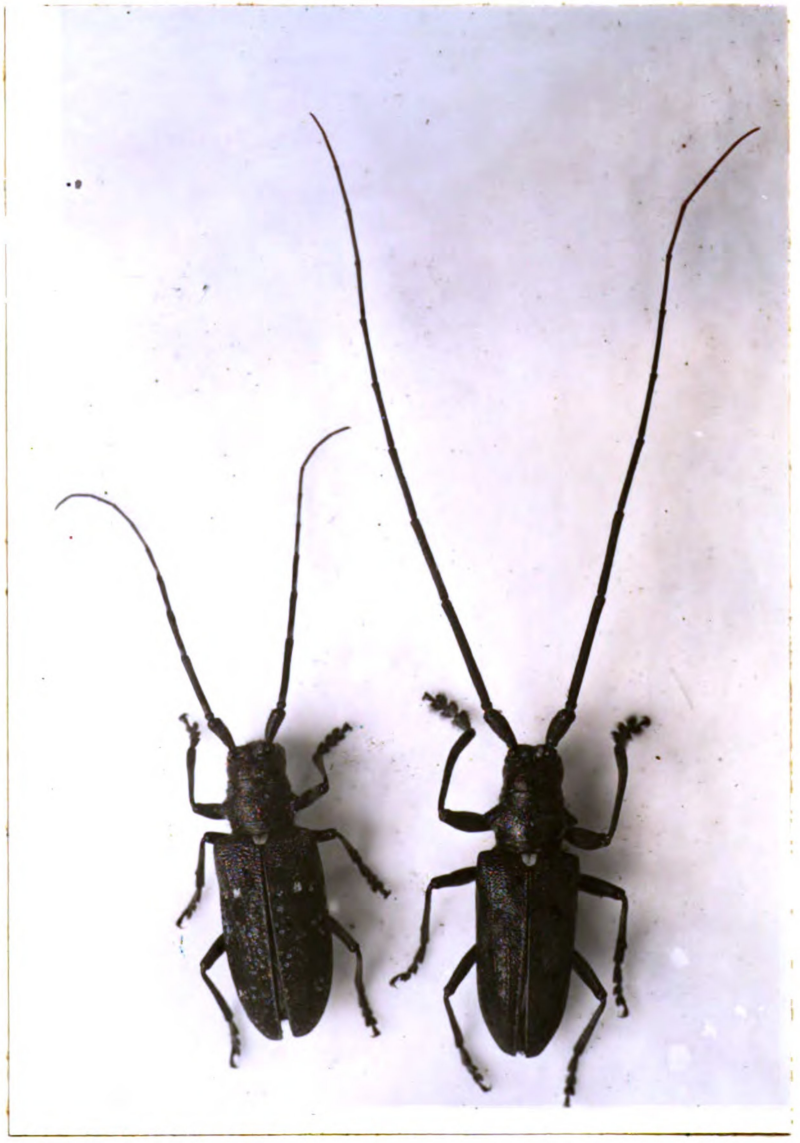
(89) Webb, J. L. 1909. The southern pine sawyer, Monochamus titillator. U. S. Dept. Agr. Bur. of Ent. Bul. no. 58, pt. 4.

(90) Webb, J. L. 1911. Injuries to forests and forest products by round-headed borers. U. S. Dept. Agr. Yearbook, 1910, pp. 341-358.

(91) Webb, J. L. 1911. Monochamus titillator probes lumber business. Am. Lumberman, July 15, p. 48.

# PLATES

PLATE I.



Adult male and female of the white-spotted sawyer, Monochamus scutellatus (Say). Male on right. X 2.

PLATE II.

Fig. 1. Size variation in males of Monochamus scutellatus (Say).

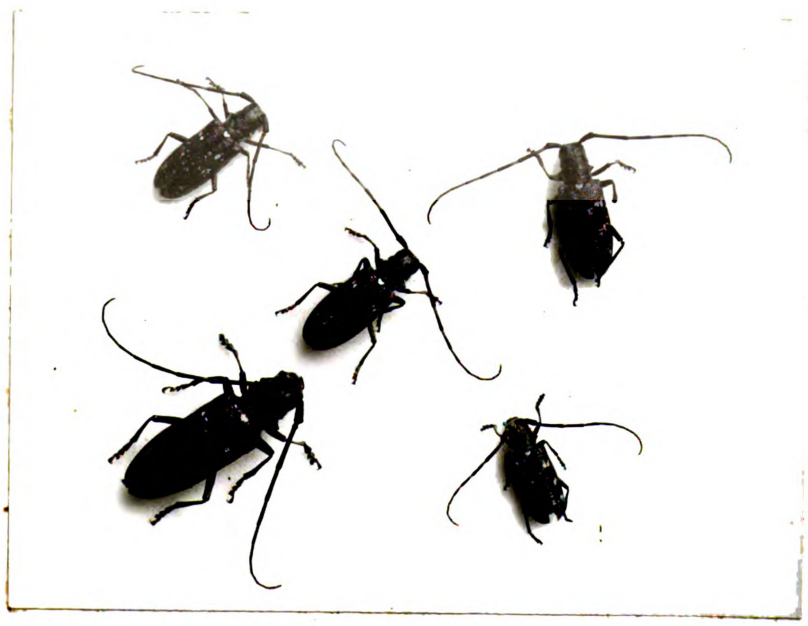


Fig. 2. Size variation in females of Monochamus scutellatus (Say).

PLATE III.

Fig. 1. Color and size variation in females of Monochamus scutellatus (Say).

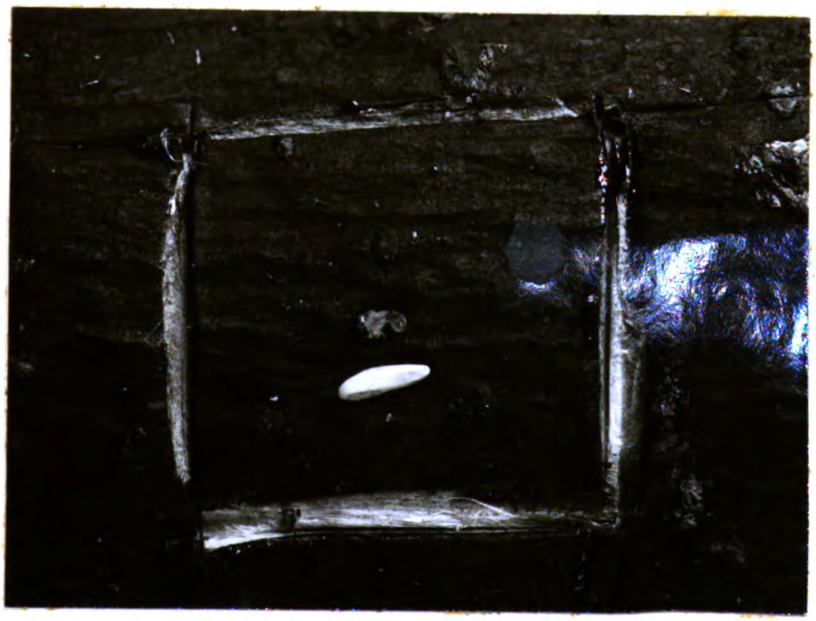


Fig. 2. Egg and newly hatched larva of Monochamus scutellatus (Say). X 4.

PLATE IV.

Sawyer work in sapwood of jack pine. Note nearly circular exit holes of adults and the more flattened entry holes of larvae.

PLATE V.

Sawyer work in heartwood of jack pine.

PLATE VI.

Longitudinal section of jack pine showing mature larvae of Monochamus scutellatus (Say). Note pupal chambers and adult exit tunnels in upper part of picture. X 1/3.

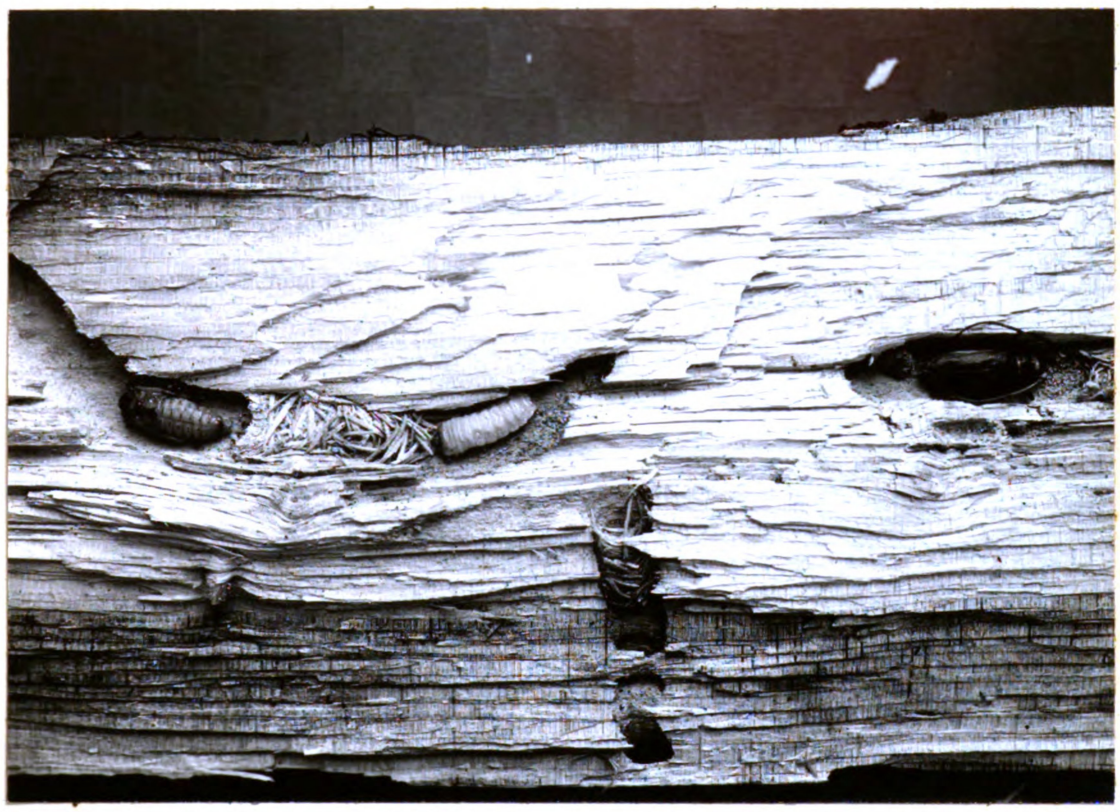
PLATE VII.

Section of white pine limb showing sawyer and bark beetle association.

PLATE VIII.

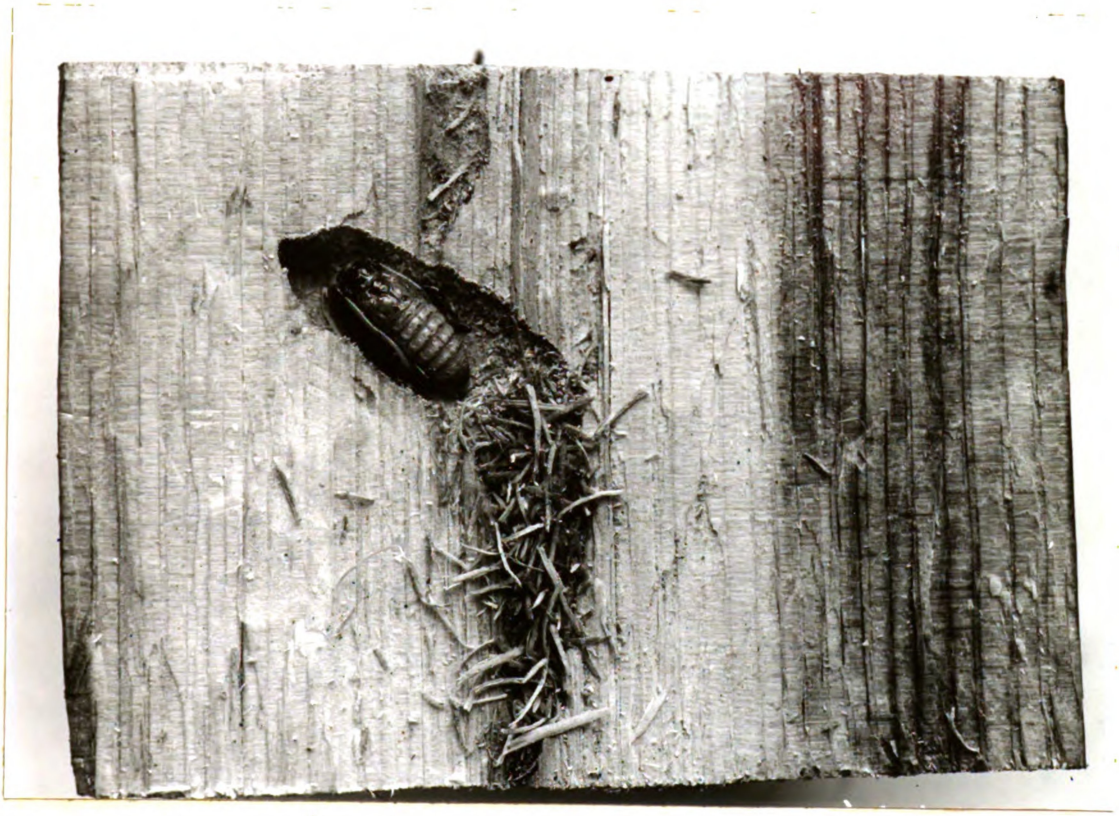
Sawyer tunnels in heartwood of jack pine.
(Slightly reduced).

PLATE IX.



Section of white pine log showing larva, pupa and newly transformed adult of Monochamus scutellatus (Say). X 2/3.

PLATE X.



Section of jack pine log showing pupal chamber and pupa of Monochamus scutellatus (Say). X 1¼.

PLATE XI.

Fig. 1. Adult exit holes of Monochamus scutellatus (Say). (Natural size).

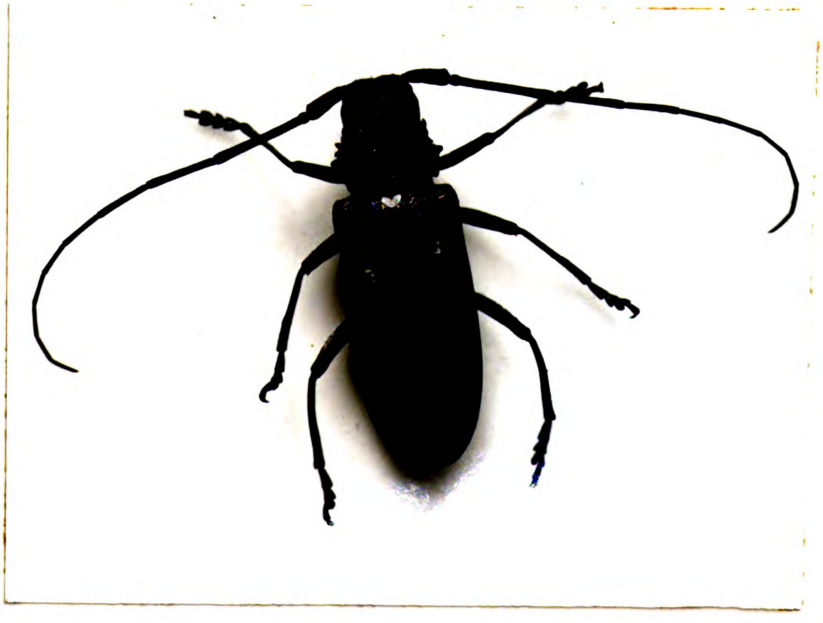
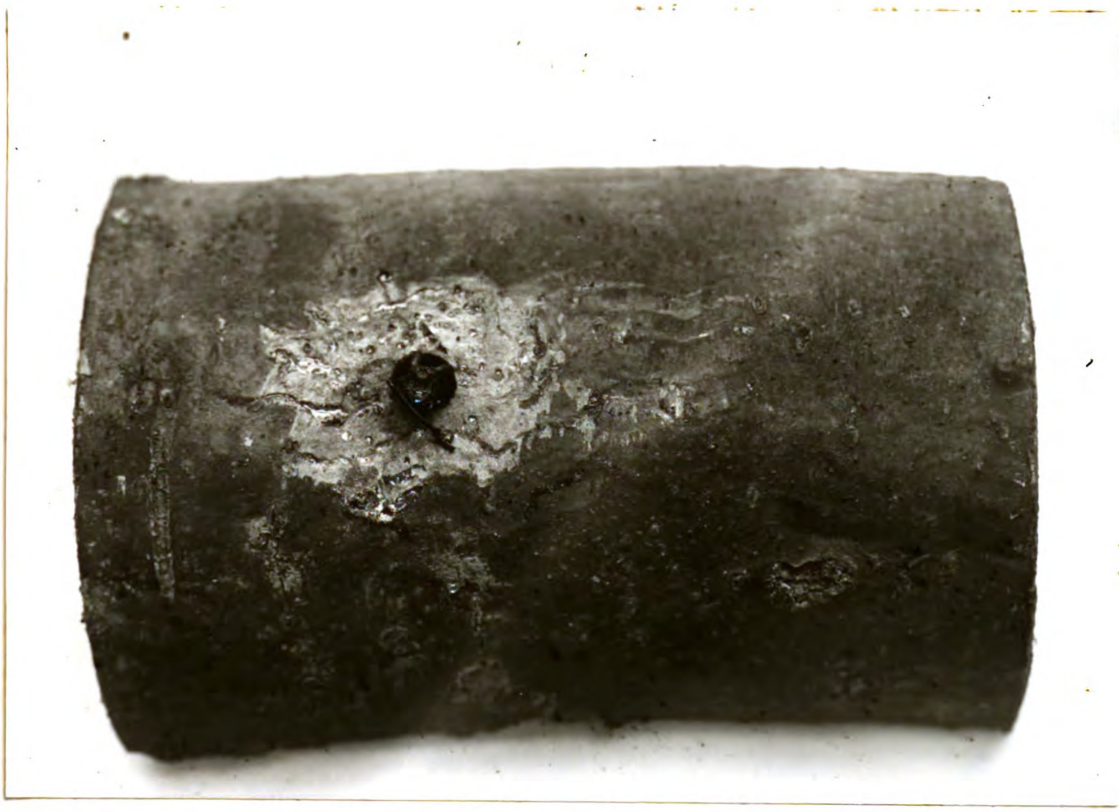


Fig. 2. Mites on head and thorax of white-spotted sawyer. X $2\frac{1}{2}$.

PLATE XII.



White-spotted sawyer adult emerging from white pine limb. (Slightly enlarged).

PLATE XIII.

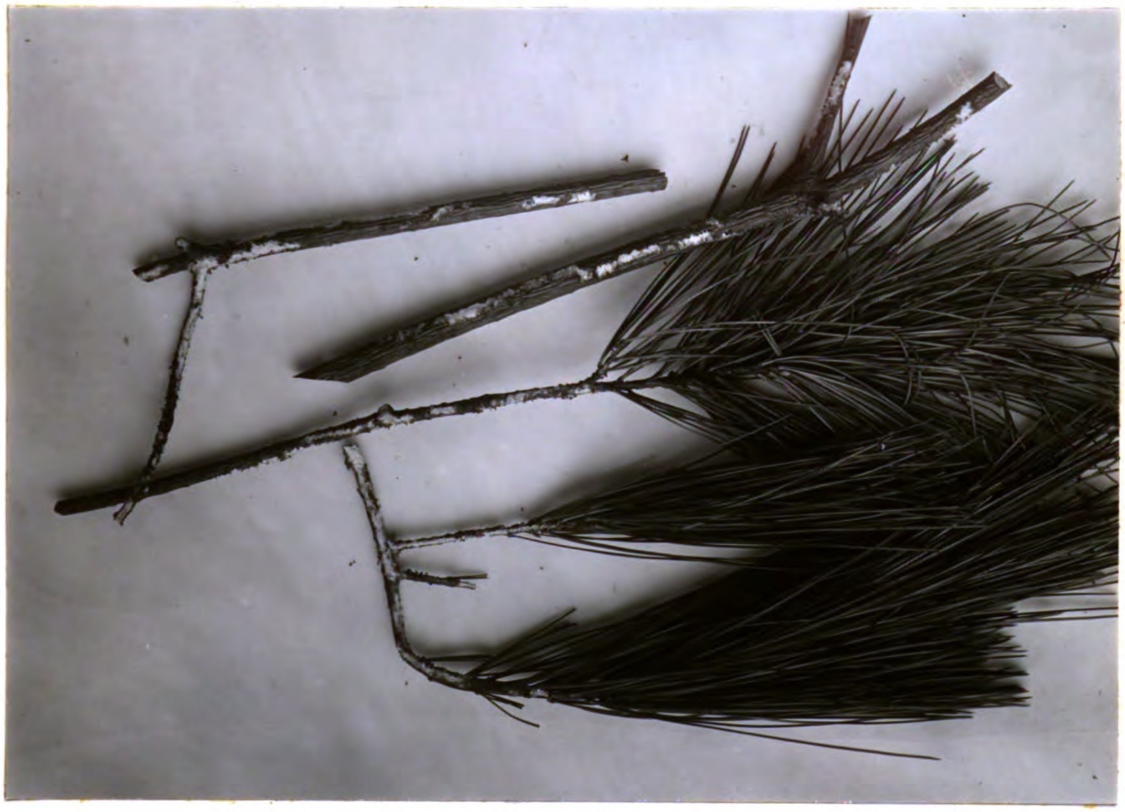
Exit hole of adult sawyer in white pine limb.

( Slightly reduced ).

PLATE XIV.

Section of balsam fir limb showing fungous growth in sawyer tunnels.

PLATE XV.

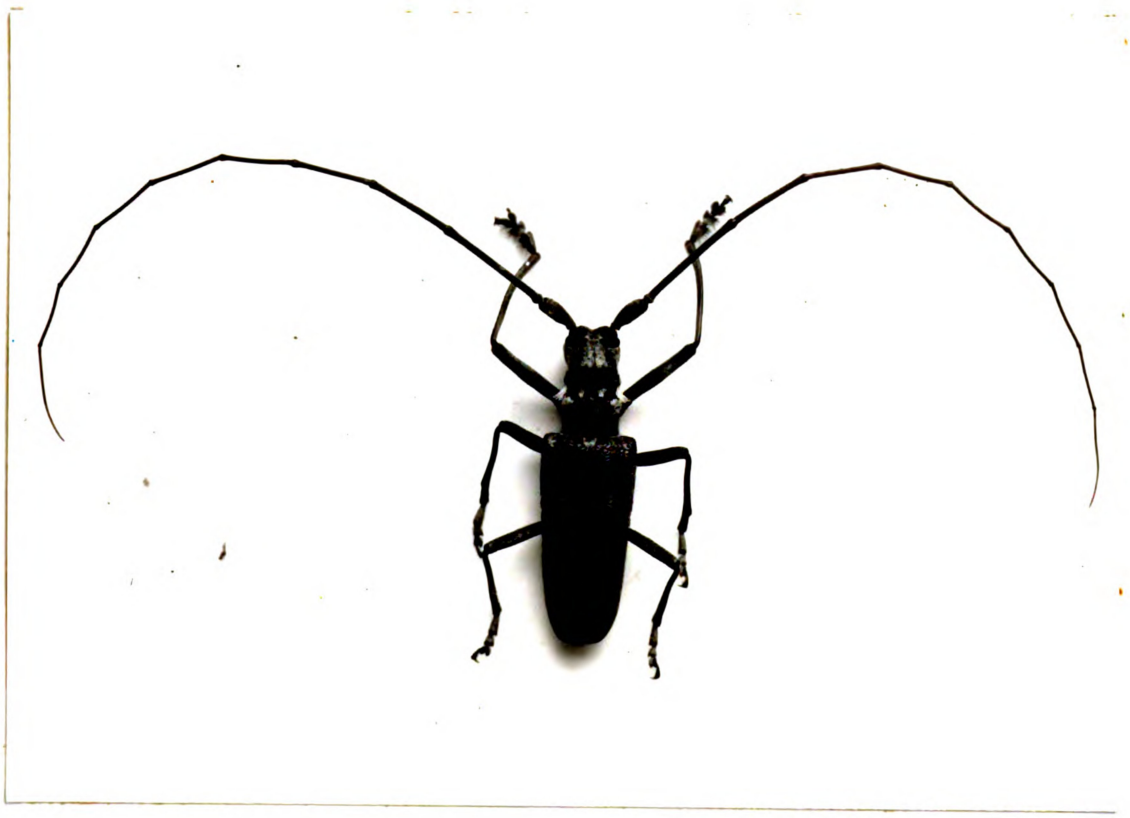


Injury to white pine twigs by adult feeding of Monochamus scutellatus (Say).

PLATE XVI.

Adult male and female of the southern pine sawyer, Monochamus titillator (Fab.). Male on left. (Slightly enlarged).

PLATE XVII.



Adult male of the grey sawyer, Monochamus notatus (Drury). X 1¼.

PLATE XVIII.

Fig. 1. Adult male and female of *Acanthocinus pusillus* (Kirby). Male on right. X 2.

Fig. 2. *Astylopsis guttata* (Say). X 3.

PLATE XIX.

Section from black spruce limb with bark removed showing pupal cell of Acanthocinus pusillus (Kirby). (Natural size).

PLATE XX.

Fig. 1. Adults of Asemum moestum Hald. X $2\frac{1}{2}$.

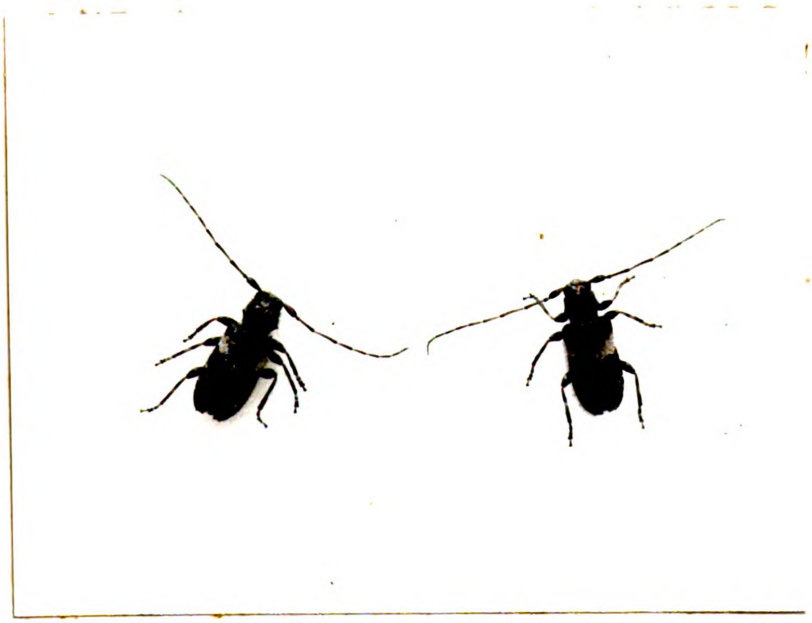


Fig. 2. Adults of Pogonocherus mixtus Hald. X $2\frac{3}{4}$.

PLATE XXI.

Fig. 1. Anoplodera canadensis (Fab.).
X $2\frac{1}{4}$.

Fig. 2. Anoplodera vittata (Oliver).
X 2.

PLATE XXII.

Fig. 1. Adult beetles of flat-headed borer, Chrysobothris scabripennis C. & G. X 1½.

Fig. 2. Larva of flat-headed borer, Chrysobothris scabripennis C. & G. X 2.

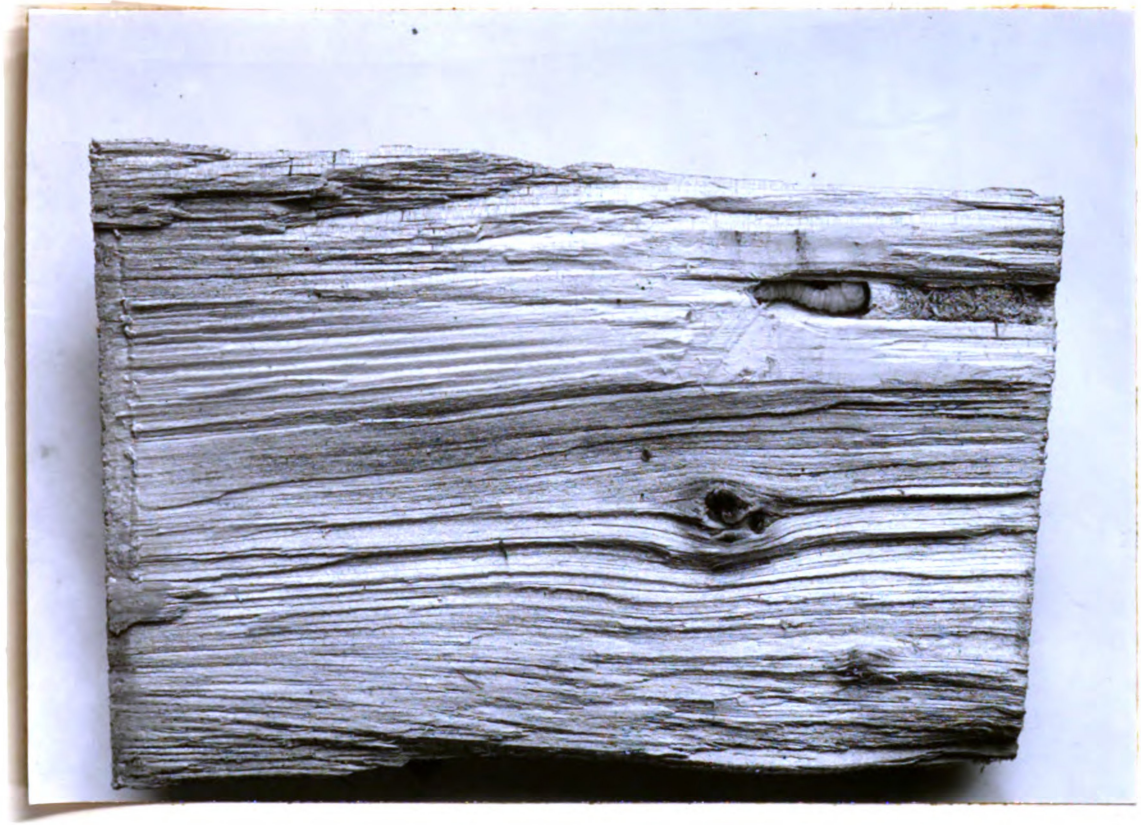
PLATE XXIII.


Section of white pine limb showing sawyer and Buprestid feeding excavations in the sapwood. A, work of the Buprestid, Chrysobothris scabripennis C. & G.; B, work of sawyer, Monochamus sp.; C, larval entry holes of Monochamus sp.; D, larval entry holes of C. scabripennis; E, adult exit holes of C. scabripennis.

PLATE XXIV.

Cross section of white pine limb showing larval tunnels of Monochamus sp. in heartwood and Chrysobothris scabripennis in the sapwood.

PLATE XXV.



Section of white pine limb showing mature larva of *Chrysobothris scabripennis* C. & G. just prior to pupation. X 1¼.

PLATE XXVI.

Fig. 1. Adults of Acmaeops proteus (Kirby). X 3.

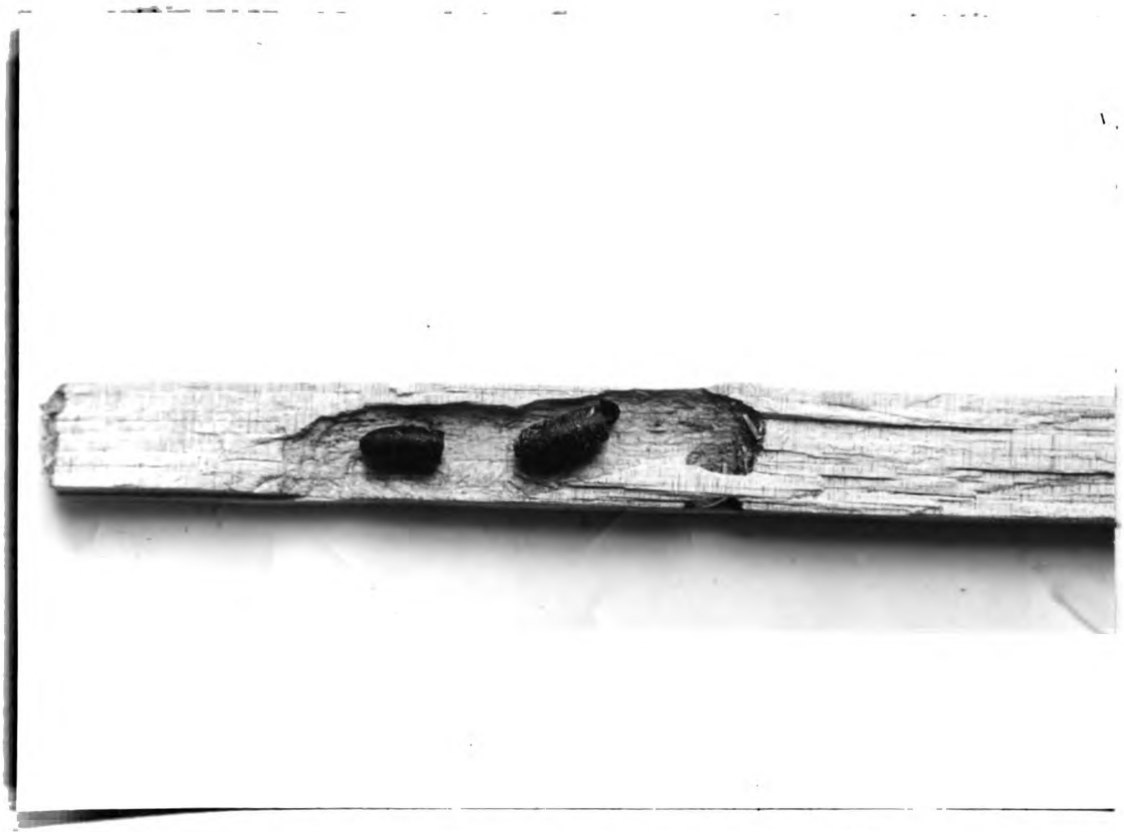
Fig. 2. Adults of Chalcophora virginiensis Drury. X 1¼.

PLATE XXVII.

Fig. 1. Adults of sawyer parasite, Ichneumon (Ephialtes) mesocentrus (Grav.).

Fig. 2. Section of white pine limb showing cocoon of Ichneumon mesocentrus in larval tunnel of Monochamus sp.

PLATE XXVIII.



Section from heartwood of white pine limb showing puparia of a Tachinid fly in Monochamus tunnel.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