STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF FORESTRY
FRED G. STEVENOT
Director
M. B. PRATT
State Forester

BULLETIN No. 7

Insect Enemies of California Pines and Their Control

By F. P. KEEN
Associate Entomologist U. S. Bureau of Entomology

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FIG. 1. A group of twenty-four thrifty western yellow pine, containing over 30,000 board feet of timber, killed in a single season by attacks of the western pine beetle. Such epidemic infestations destroy some of the very finest commercial timber. (Author's illustration.)

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PREFACE.

With the constantly increasing value of pine stumpage has come a growing concern on the part of timber owners for its protection, not only from fire but from insects and disease. This has resulted in a widespread demand for information on the insect enemies of the pine and the best methods of combating them. To meet this demand, this circular has been prepared for the State Board of Forestry through cooperation with the U. S. Bureau of Entomology, whose specialists have been studying the forest insect problems of California during the past twenty years.

While much of the information contained in this circular has been previously published in a number of miscellaneous government bulletins, state bulletins, entomological journals and textbooks, most of these are either out of print or are not easily obtained by the interested timber owner. In addition, a great deal of new material, including unpublished notes of the author and other forest entomological workers, has been included, in order to bring the information up to date and give the timber owners and foresters the benefit of results obtained in recent investigations and control experiments.

The descriptions of the insects and their work are grouped, as far as possible, according to the natural relationships of the insects, while the groups themselves are arranged in order of their importance in the forest. The host lists and keys to the work enable the forester to find any particular insect from the standpoint of the tree and part of the tree affected. Natural-sized photographs have been used wherever possible, as it was felt that these would be of the most assistance to the layman in recognizing the destructive species. In order to do this it was necessary, in nearly every case, to take original photographs. Published pictures or those furnished by other workers have been acknowledged in the text.

The author wishes to express his sincere appreciation and thanks to all of those who have so generously assisted in the preparation of this circular and especially to the members of the California State Board of Forestry, State Forester M. B. Pratt and Deputy State Forester W. B. Rider, who have made its publication possible; to co-workers of the Forest Insect Investigations Division of the U. S. Bureau of Entomology who have assisted in many ways, especially Mr. J. M. Miller, who has thoroughly reviewed the manuscript, and Dr. H. E. Burke, who has given many valuable notes on a number of different groups; to other forest entomologists, notably Dr. E. C. Van Dyke of the University of California for certain photographs, notes on many species, review and criticism of the manuscript; Dr. W. M. Blackman of Syracuse University and Prof. R. W. Doane of Stanford University for a number of suggestions and corrections throughout the paper; and to associates among the foresters, especially Mr. S. R. Black of the California Forest Protective Association, Mr. T. D. Woodbury of the U. S. Forest Service and Prof. Emanuel Fritz of the University of California,

who have reviewed the manuscript and given many helpful suggestions from the standpoint of the men who, it is hoped, will find the circular of interest and usefulness.

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February 1, 1928.

THE ROLE OF INSECTS IN THE FOREST.

Insects are an essential part of the vast association of living, growing and dying organisms which we call a forest. No forest would be complete without them. Many of them are of great benefit to the forest in bringing about the rapid deterioration of fallen limbs and dead trees; thus giving room for new growth.

On the other hand, certain insects, because of their attack upon healthy living trees, are justly considered by man as distinctly injurious to his and the forests' best interests. When the insects play a dominant role as forest destroyers their work is soon brought to man's attention and ways and means to control their natural appetites and desires are planned.

FIG. 2. A normal infestation among the big sugar pines of the Sierra region. After a few weeks of struggle, these big pines succumb to the attacks of the mountain pine beetle, and in after years become naked snags or "ghost trees." (Photo by J. M. Miller.)

Insects are one of the most important agencies of tree destruction. Just as with human beings more people die from disease than from accidents, so also in the forest more trees die from insects and disease than from all other agencies. The total annual loss thus occasioned is enormous. Recent estimates place the loss for California's pine stands at 500,000,000 board feet annually, which at $4 per M b.m. represents a monetary loss of $2,000,000. Much of this is only the normal decay of the forest which is replaced by younger growth; so that which concerns us most is not this total loss, but that proportion of it which is excessive and unnecessary and is not matched by forest growth.

Normal Infestation.—All of the important forest insects of California are native to our forests. They have been killing trees for

centuries and their ancestors killed trees before them, probably back to the very beginning of the forests. (Fossils of forest insects have been found in cretaceous rocks.) The killing of forest trees by insects is, therefore, not new, as some people suppose.

Every year a certain percentage of the forest stand succumbs to the insects. Usually this loss is less than the annual increment and continues unnoticed. Such a loss is termed a normal or endemic infestation, and can be disregarded since it is a normal process of nature, and does not diminish the forest capital.

Epidemics.—Periodically conditions become particularly favorable for the insects. Their enemies are reduced in numbers; the resistance of the trees is lowered or a large quantity of slash or other favorable breeding material is available for them and they become very abundant and for several years kill more timber than will be replaced by normal

FIG. 3. An epidemic infestation of the western pine beetle on a slope of the Klamath River Canyon in Northern California, representing a loss of 400,000 board feet of commercial timber per year to each square mile of infested forest. (The yellow foliage of dying trees shows white in the photograph.) (Original.)

growth for many years. Such a condition is termed an epidemic infestation, and when it occurs in valuable stands it should receive immediate attention and drastic methods should be adopted to bring it to an end.

THE IMPORTANCE OF INSECT LOSSES IN MATURE TIMBER.

The most severe forest insect losses usually occur in the mature timber stands. Here are found many old trees long since past their prime and an easy prey to the activities of bark-boring beetles. From the standpoint of the continuation of the forest, the sporadic or even continuous killing of the old trees is not important; but from the standpoint of the timber owners such trees contain the finest quality and the

most valuable part of the stand, and their protection until the day of the harvest is of the greatest importance. When an epidemic occurs, insects not only take many of the oldest and largest trees, but also kill medium sized and small trees which are growing vigorously. In western yellow pine forests, over limited areas, as much as 10 per cent of the stand may be killed in a single year, and 50 per cent of the stand during the course of the epidemic. In lodgepole pine 90 per cent of the stand may be wiped out by one invasion. Such a loss can only be replaced after many years.

Of the California pines, lodgepole pine probably suffers the most from insect attack. Periodically the lodgepole stands over large areas are wiped out by bark-beetles, mainly the work of the mountain pine beetle (see page 33). In Yosemite National Park, vast areas of white snags or "ghost trees" give evidence of the old beetle invasions, and

FIG. 4. Many square miles of lodgepole pine forest in the Yosemite National Park have been completely killed by the mountain pine beetle in the last thirty years. The snags stand as ghost trees reminding one of the powers of these small beetles. (Photo by J. E. Patterson.)

recent epidemics have killed additional lodgepole pines over other parts of the state. In this work the beetles have often been aided by a needle miner (see page 79) which, by completely defoliating the trees, so weakens them that they are unable to resist the bark-beetle attacks.

Of the commercial pines, western yellow pine is undoubtedly the greatest sufferer. The hosts of insects which attack it are legion; over a hundred different kinds of injurious insects have been recorded as feeding upon it and doing various amounts of damage. Estimates made from check cruises in various parts of the state indicate that the annual loss of western yellow pine from insects, principally the western pine beetle, exceeds 300,000,000 board feet, enough timber to keep several modern sawmills in continuous operation.

Sugar pine, while not attacked by as many different insects as its neighbor the western yellow pine, has a great many destructive insect enemies which cause the death of timber estimated at over 60,000,000 board feet annually. Its principal enemy is the mountain pine beetle.

Jeffrey pines suffer a heavy loss at times from the Jeffrey pine beetle and the California flat-head borer.

The other California pines, of less commercial importance, all have their insect enemies which do more or less damage to the mature trees as well as to the younger growth.

IMPORTANCE OF INSECTS IN SECOND GROWTH STAND AND NURSERY STOCK.

Insects play an important role in second growth stands. Probably their natural function here is to act as one of nature's checks and balances, and by killing off the weaker individuals assist the stronger to survive. At times, from man's standpoint, they carry this work too far and wipe out large patches of young growth or bring about a complete revision of forest types. For instance, in one locality in Modoc County, a bark-beetle epidemic in a mixed second growth stand of western yellow pine and white fir killed out all of the pine and turned the area into a pure fir stand. In some sections of the Yosemite region the complete destruction of the lodgepole pine by bark-beetles is changing the forest into a hemlock stand. There are a great number of insects which cause only slight damage to mature trees but which can bring about serious injury to young, growing terminal shoots. Thus insect damage to nursery stock may become a serious problem, when the virgin timber is removed and artificial reforestation attempted.

The insects which attack young pines are, in general, different from those which prey upon the mature trees. Here the engraver beetles, the bud moths, and the twig weevils are of more importance than the pine beetles. It is also more than possible that when the virgin timber is cut these enemies of the second growth pines will play the leading role.

THE INSECT INJURY TO TREES OF SPECIAL VALUE.

The destruction of trees of special value from a recreational or aesthetic standpoint has just recently come into prominence due to the rapid progress in recreational forest development. A few stately forest trees greatly enhance the value of summer home and hotel sites, and the insects in destroying or injuring such trees have frequently reduced the value of the location by many thousands of dollars. It is very difficult to estimate the amount of such losses, but they have already assumed serious proportions and will become more and more serious as forest recreational development progresses. Especially in the mountains of southern California do the bark-beetles present a most serious problem.

WHAT THE INSECTS DO.

At every stage in the life of a tree it is fed upon by insects. Certain insects attack the seedling, the sapling, the pole, the tree when it reaches full growth, when it reaches old age, and even after its death insects feed upon the remains. Every part of the tree is attacked, from the roots to the tips of the needles, and from the outer bark to the very heartwood—nothing escapes. The seriousness of the injury depends upon the part of the tree attacked and the habits of the insects themselves. Some of them bite and chew, some of them suck the juices, and others bore into the wood.

THE BARK-BORERS.

The term "bark-borers" usually refers to those insects which bore between the bark and the wood and kill the trees or seriously injure them by a girdling process. They include some of the most destructive species with which we have to deal; such as the pine bark-beetles and the flat-headed borers. They are all insects which in the larval stage chew their food, and construct their tunnels by biting their way through the plant tissue.

THE WOOD-BORERS.

The wood-borers are also a group of insects with biting mouth parts which they use to chew their way through the hard wood of the trunk or limbs. Some of these attack the living trees, but most of them attack the wood of injured, dying, or felled trees. Unless they are also bark-borers their work rarely is of importance in causing the death of the trees, but is of most concern in causing defects in the lumber. Many species only breed in old, rotting wood, in which cases they are of benefit in hastening the distintegration of forest debris.

THE LEAF-FEEDERS.

The leaf-feeders are usually caterpillars, slugs or adult beetles which destroy the pine needles by chewing them. Occasionally these insects cause the complete defoliation of trees over large areas. When the terminal buds are also destroyed such a defoliation often proves fatal to the trees. Usually, however, the buds are not injured and the final result is a weakening of the trees, a retardation of their growth, and an increasing of their susceptibility to bark-beetle attack.

THE SAP-SUCKERS.

Such insects as the plant lice and scales have mouth parts adapted to sucking the plant juices. While this group is of great importance to the agriculturist, they are not so much so to the forester. Comparatively few sap-sucking insects do any serious damage to the pines.

THE NATURAL CONTROL FACTORS AND INFLUENCES.

The causes of insect epidemics are many and complexly inter-related with other factors in the environment. Usually there is a balance between the forces of Nature which keeps the insects in their normal place. An increase or decrease in beetle activity is the result of a disturbance of this balance. Thus an abundance of insects depends upon an abundance of their food supply, suitable temperature and moisture conditions for their optimum development, and an absence of the enemies which normally hold them in check; while a scarcity of insects usually follows a scarcity of food supply, unfavorable breeding conditions, and an adundance of enemies.

CLIMATIC INFLUENCES.

Climatic influences not only have a direct effect upon the insects but often affect their food supply and provide favorable conditions for their attack.

Temperature.—Extremely high or low temperatures are often fatal to various forest insects. The western pine beetle can be killed in bark exposed to the direct rays of the sun when the air temperature is over 85° F., since the inside of the bark reaches a fatal temperature of over 110° F. Under natural conditions bark-beetles are often killed by the heat of the sun on the south side of exposed infested trees and on the tops of logs. Also very cold winters have proven fatal to the western pine beetle and a sudden freeze in early spring after activity has started may also cause some mortality. Insects in general have a comparatively small range of temperatures (50°–95° F.) within which they are the most active; and the optimum temperature for many of the temperate zone species appears to be about 77° F. Therefore, years of abnormally low temperature reduce the activity of the insects and limit their destructiveness. On account of the colder conditions, less forest insect destruction occurs at high elevations than at the lower levels.

Moisture.—Moisture has its effect not only upon the activities of the beetles but upon their hosts. We do not know to what extent forest insects are affected by air humidity. But we have found that precipitation in its effect upon the trees is of considerable importance in the development of forest insect epidemics. Dry seasons, such as occurred in 1924, bring about a decrease in the vitality of the trees and seem to favor the development of certain insect species, notably the western pine beetle and the flat-headed borers. Excessively wet seasons may also favor the development of certain other injurious species, but as yet we know of no cases where this has happened.

THE INFLUENCE OF THE FOOD SUPPLY.

The abundance of favorable breeding material is often a very important factor in the increase or decrease of an insect species. The amount of available material not only depends upon the abundance of the host tree, but upon the number of individuals which offer favorable

breeding conditions for the insects. Over-mature or decadent trees, slash, windfalls, snowbreak, lightning-struck trees, all offer favorable conditions for the attack and development of destructive bark-beetles and borers.

Mature Timber.—A high percentage of mature or decadent timber in any forest often presents ideal conditions for bark-beetle attack. The beetles seem to prefer trees in which the growth has been retarded, and in this respect the old, mature trees offer suitable material.

Lightning.—Lightning-struck trees appear to be very attractive to bark-beetles, and very few escape death if beetles are present in any numbers. In fact, unless lightning-struck trees are completely shattered, they rarely die unless attacked by the insects.

Windfalls and Snowbreaks.—Under natural conditions, windfalls and snowbreaks furnish breeding material for a great many destructive as well as beneficial insects. Such material is probably the natural habitat for many species which at times attack the living trees. Several severe epidemics of bark-beetles are known to have originated in areas of windblown timber.

Slash.—Fresh slash, by which is meant the debris left from the cutting of trees in the woods, is very attractive to destructive forest insects, and unless an area is exceptionally free from insects the slash from a logging operation will be found to be filled with insects of many kinds.

In the stumps will be found the red turpentine beetle and insects which usually attack the base of mature trees. In the cull logs and butts will be found those insects which usually attack the main trunk of the standing trees, while in the brush and smaller limbs will be found only such insects as usually attack these parts of the standing trees.

Slash appears to exert an attractive influence and to draw in insects from the surrounding area. These usually not only enter the slash but attack the standing trees in the vicinity of the cuttings and often cause considerable damage.

However, slash and windfalls often prove to be poor material for the development of normal broods, and frequently many of the broods die in the slash, leaving fewer beetles to emerge than made the first attacks. But due to the greater concentration of beetles, the emerging progeny may still be very plentiful. Slash in certain timber types, however, is a menace to the forest unless it is properly handled.

The easiest and safest thing to do is to make the logging operation continuous and thus furnish a continuous supply of slash throughout the flight period of the beetles. This will continue to attract and absorb the beetle broods, and due to the poor development in the slash and the number of beetles destroyed by removal of logs from the woods, the beetle population of the area will be gradually reduced and the forest protected.

Slash disposal through burning would be beneficial provided it included the large limbs, cull logs and stumps and was done during the summer before the beetles emerged. But this is not the usual practice in slash disposal and since summer burning is extremely

dangerous it is not advocated because of entomological considerations unless for some reason the cutting operations are discontinued during the summer, and the slash on the ground is filled with potentially destructive insects.

The present practice of burning the tops and smaller limbs only destroys the relatively innocuous portions of the slash and since it is usually carried on late in the fall after many of the beetles have emerged is of little benefit in destroying the more harmful bark-beetles.

Insects play an important role in bringing about the disintegration of the larger pieces of slash left in the woods and in this respect are of considerable benefit. The insects which do this work are quite different from those which kill the trees, and so the cleaning up of the woods by the burning of old logs and debris, as has been advocated by some, would be of no benefit in protecting the forest from the destructive pests.

Forest Fires.—The timber destruction from forest fires is increased through the agency of bark-beetles. A forest fire of sufficient severity to scorch the bark, cambium, and foliage of yellow pine makes these trees particularly attractive to bark-beetles and draws beetles into the burned area for a distance of two or three miles. Many trees which are moderately scorched and would otherwise survive the fire injury are attacked and killed by the beetles.

Although fire-injured trees attract bark-beetles, they frequently do not provide favorable breeding material for them. Eggs are laid in the fire-scorched trees but the new broods fail to develop properly and often fewer beetles leave the trees than made the original attack. For this reason fire-scorched areas do not breed up insect epidemics to become a menace to surrounding timbered areas.

Neither do fires have much effect in destroying the destructive bark-beetles present on an area at the time of the fire. It has been demonstrated that the beetles protected by the thick bark of the trees can withstand a very hot ground fire with no ill effects. Often "light burning" has been advocated as a means of controlling bark-beetles, but studies have shown that such fires are more apt to have the opposite effect. The destructive tree-killing beetles never breed or inhabit the forest litter and duff and therefore are never killed by a light ground fire, and can only be killed in the trees by a fire severe enough to burn the bark from the trunks. Such a fire obviously would do more damage than good.

In the case of the Pandora moth, a forest insect which defoliates the pines, light burning has been shown to be quite effective in destroying the caterpillars and pupæ, but this method of control is of doubtful expediency and the benefits probably would be offset by an increase in the bark-beetle losses.

In general, therefore, it may be said that fires are not only destructive to timber in themselves, but increase the damage from forest insects to living trees on areas covered by fire.

THE INFLUENCE OF NATURAL ENEMIES.

Like everything else in Nature, the insects have their natural enemies, which under normal conditions tend to hold them in check. These enemies may be other species of insects, birds, or disease. When the

enemies become too numerous they rapidly destroy their own food supply and soon suffer from starvation. With the decline of the enemies, the insects again have an opportunity to increase. This factor in large measure accounts for the periodic fluctuations in beetle activity.

Beneficial Insects.—The question is commonly asked "Are there no insects which could be trained to feed upon and destroy the destructive pine pests?" The answer is that there are already a number of insects which prey upon the destructive species and probably in normal years are an important factor in keeping them under control. Moreover, the destructive pine insects of California are all native species, and have their native enemies already on the ground and preying upon them. There is little hope, therefore, of introducing any efficient parasites or predators from foreign countries or changing the habits of any of the native species to make their work more effective.

There are a large number of insects belonging to different orders and families which devote their lives to feeding upon other insects. In general these are divided into two groups, (1) the predators, which devour their prey, and (2) the parasites, which live within or on their host during some stage of its life and gradually consume it.

The most important predators of the pine bark-beetles belong to two families of beetles, the clerids and the ostomids. The adults lie in wait for the attacking bark-beetles and catch them as they light upon the trees. In the larval stage they prey upon the larvæ of the bark-beetles. The larvæ of certain species of flies (*Diptera*) and certain caterpillars (*Lepidoptera*) are also predaceous on other forest insects.

Most of the parasites belong to two or three families of small wasps (*Hymenoptera*). These have long ovipositors with which they deposit their eggs in the insect host, where it hatches and grows to maturity, finally killing its victim. There are a large number of such parasitic wasps and nearly every forest insect has its own particular wasp enemy.

The larvæ of the large round-headed borers are often unwittingly beneficial when by feeding on the inner bark of the infested trees they rob the bark-beetles of their food supply. These larvæ are very indiscriminate feeders and probably chew right through any bark-beetle larvae that happen to get in the way.

Birds.—Many species of birds are insectivorous and under normal conditions probably do good work in holding the destructive forest insects in check. The woodpeckers especially are important enemies of the bark-beetles and bark-borers. Often the outer bark from yellow pines infested by the western pine beetle will be almost completely chipped off by the woodpeckers in their search for the grubs. In fact, cruisers often recognize a bark-beetle infested tree by the woodpecker's work on the trunk and the scattered bark flakes surrounding the base of the tree. Bark counts have shown that on the sections of bark searched by the woodpeckers, 75 per cent of the normal brood of bark-beetles have often been destroyed. However, the birds do not feed entirely upon the destructive species, but take the beneficial species as well, so that they can not be entirely relied upon to destroy the injurious species.

Disease.—Insects, as well as man, are subject to diseases, and these at times are perhaps accountable for the complete suppression of some injurious pest. But as yet very little is known about such diseases or how they might be encouraged to destroy the harmful forest insects.

There is often a close correlation between tree diseases and insects, and at times it is hard to determine just which agency is responsible for the death of the tree. In some cases the insects follow some diseased condition of the tree and in other cases diseases of the tree are brought in by the insects.

THE ARTIFICIAL CONTROL OF PINE INSECTS.

The control of insects which injure forest trees, scattered as they are over large areas of virgin forest, might appear, at first thought, to be an insuperable task. Although it does offer much greater difficulties than the control of farm or orchard pests, where only a limited area need be considered, still the control of some of the more important destructive forest insects has not proven to be an impossible undertaking.

GENERAL PRINCIPLES.

The control of our native forest pests does not mean to imply an attempt at their extermination. Such a course is not only impossible but probably not even a desirable objective, since the insects have a real part to play in the scheme of Nature. What control does mean is the re-establishment of the natural checks and balances which hold the destructive insects within certain bounds in a normal forest, and which for one cause or another have ceased to function properly.

To do this it is essential to have a complete knowledge of the life history and habits of the insects as well as to know something of their ecology. Only then can a proper diagnosis of the trouble be made, the seat of the trouble discovered, the proper remedy applied and applied at the proper time. There are three phases of forest insect control, namely, prevention, detection and suppression.

Prevention.—Until recently, the prevention of forest insect losses has not received much attention. While we can not produce favorable weather conditions or regulate other natural control factors, still there are certain things which can be done to improve the general health of the forest; to bring about unfavorable conditions for insect propagation and thus lessen the damage.

Intensive forest management offers one solution. As our forests become more intensively used, a great deal of insect loss can probably be avoided by the gradual weeding out of trees susceptible to insect attack—trees which are suppressed, overmature, or weakened from various causes; through the prompt removal of infested trees; and by the handling of cutting operations so that destructive insects will not be allowed to breed up and escape from the debris.

The use of repellents or mechanical tree protectors offers another solution chiefly for the protection of individual and particularly valuable trees near summer homes or in parks. As yet no repellents have been found which are entirely satisfactory. Wire screen wrapped around the trunks of pines, laced along the seams and closed with dirt at the base has proven effective in keeping out some of the larger bark-beetles and in saving the trees.

Detection.—Before any action can be taken looking toward the control of pine insect pests, information must be secured as to the extent of the damage and the insect or insects responsible for such damage. This is a task which devolves upon the timber owner, the state or federal forest rangers, or other guardians of forest property. The primary purpose of this circular is to assist these men in recog-

nizing insect damage so that they can efficiently accomplish this detection work.

If trees appear to be dying through any forest tract they should first be examined and, if possible, the cause of the trouble ascertained. The preliminary diagnosis and keys to typical insect work on pages 98–99 should be of assistance in determining the insects responsible for the damage. Then if the trouble is widespread and an estimate of the total damage is desired, lines should be run through the infested area and the number of dying trees counted in a four or five chain strip on either side of the line, and the result of such a sample strip count applied to the total area affected. If the topography is flat, the lines can best be run along section lines, or in any direction through the forest by the use of compass and pacing. If the topography is rough, the sample strips can best be run along ridges or following the contours. Viewing the infested area from lookout points with a count of the visible number of infested trees, is another helpful way of making an estimate of the damage, but such counts should be corrected by an intensive cruise of at least 5 per cent of the area viewed. If the area is large, the viewing from lookout points, strip counts and the intensive cruise of sample areas will all be necessary to secure a satisfactory estimate of the extent and amount of the damage.

Suppression.—After the trees have been attacked or killed, direct suppression methods are called for. These consist of destroying the insects on or in the infested trees before they have had a chance to escape and attack other trees, or trapping the insects in logging slash or cull material and removing them from the woods.

The use of poisons or sprays has only a limited applicability in the suppression of forest insects. At most such methods can be applied only in the control of insects attacking particularly valuable trees. As yet no attempt has been made to suppress outbreaks of defoliators over large forested areas or to control the forest insects which bore into the twigs, the cones, or the wood of our forest trees. The suppression methods which have been used under forest conditions are those concerned with the control of the bark-beetles which kill outright many trees in a single season. Methods of bark-beetle control have received considerable attention in the past twenty years, and since they are of the greatest importance to the forester and timber owners they are discussed in considerable detail in the following paragraphs. Special methods of control for the forest pests, other than the bark-beetles, are given under the discussion of each group of insects.

BARK-BEETLE SUPPRESSION METHODS.

The methods of control which have been successfully used in destroying the pine bark-beetles are as follows:

1. Felling the trees and burning the infested bark.

2. Peeling the infested bark from the trees either with or without felling the trees.

3. Felling the trees and placing the bark so that it will be exposed to the direct rays of the sun, either with or without peeling it from the tree.

4. Felling the trees and submerging the infested logs in water.

5. Preparing trap trees to absorb the beetle broods and later destroying them by one of the above methods.

6. Logging the infested area and removing the beetles either in the logs or destroying them in the slash.

Since most of the destructive bark-beetles confine their attacks to a few species of trees, control can be carried out by treating just the affected host trees.

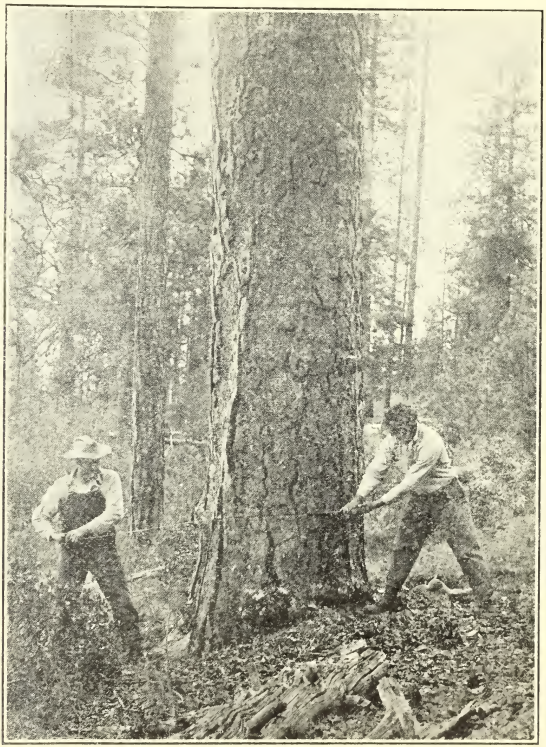

FIG. 5. Felling the infested tree is the first step in bark-beetle control. Note how the woodpeckers have riddled the outer bark of this infested tree in their search for the western pine beetle grubs. (Author's illustration.)

1. **Burning the Bark.**—This is the method most commonly used in the control of the western pine beetle. It is probably the cheapest artificial control method now available and is applicable to the control of any bark-beetle.

The infested trees containing the live broods of beetles are located by their characteristic color or boring dust in the crevices of the bark. They are then felled and the bark is peeled from the top half of the fallen trunk and piled along the sides. If a group of trees is infested they are felled together and only the upper sides of the exposed trunks on the top and sides of the pile are peeled. The limbs are trimmed and the top is cut off and all piled back over the trunks. If the forest floor is at all dry, a fire line is constructed by scraping away all of the litter and duff down to the mineral soil for a width of about three feet and completely encircling the tree, and the entire pile is then burned. Ordinarily the fire is not hot enough to burn the logs and, if at all accessible, they can be used for lumber later.

The trees should be felled either up or down hill and away from reproduction and heavy patches of brush and never across the slope of

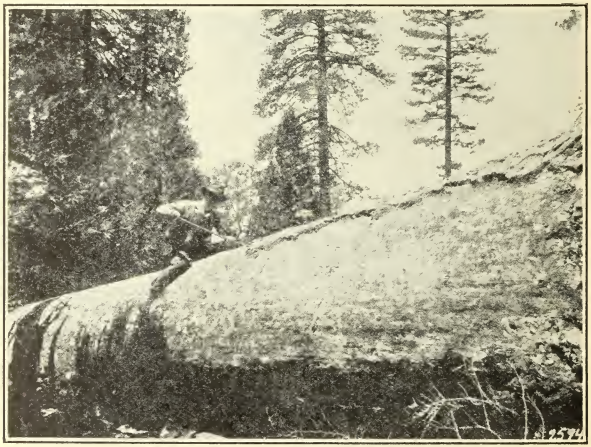

FIG. 6. Peeling the infested bark from the upper half of the felled tree is the second step in western pine beetle control. This is a giant yellow pine of the Sierras which succumbed to the attacks of the beetles. (Photo by J. M. Miller.)

a hill, if it can be avoided, since a broad flame is much more difficult to handle than a narrow one.

The fire should be regulated to give enough heat to consume the infested bark, but should not be so big as to make it difficult to control. In wet weather pitch will have to be supplied to sufficiently burn the bark, while in dry weather all of the tops, limbs and even needles will have to be thrown outside of the fire line in order to keep the fire from becoming too large. In wet weather burn with the wind and uphill in order to create enough draft to consume the bark; in dry weather *never* do so, but burn downhill and against the wind so as to be able to control the fire. Burning, if done by experienced men, can be handled without injury to the forest. On one control project burn-

ing was carried out throughout the summer of 1924, which was one of the worst fire years in California, without the least damage to the area.

2. **The Peeling Method.**—This method has been widely used in the control of the mountain pine beetle. In general it is applicable to the control of any of the bark-beetles whose immature forms, the larvae and pupae, are exposed when the bark is removed from the tree.

The tree is usually felled and with the aid of an axe or barking "spud" the infested bark is removed from the log and scattered about so that the insects are exposed to both sun and air. If the insects are nearly full grown and the bark falls in protected spots in the shade of the log, some of the beetles will escape the treatment and continue their development.

FIG. 7. The third and final step in western pine beetle control is the burning of the infested bark along the side of the fallen tree. A wide fire line is raked around the tree to prevent escape of the fire to the adjacent timber. With proper precautions burning of the bark can be carried on at any season, but is usually confined to late fall, winter and early spring. (Photo by J. M. Miller.)

In the control of the mountain pine beetle in lodgepole pine, the trees are often peeled with long-handled spuds without felling the tree, since the beetles are usually only in the basal part.

3. **The Solar Heat Method.**—Recently it has been found that when the air temperature is above 85° F. enough heat will be developed in peeled bark or in thin unpeeled bark on the tops of logs to kill the pine beetles in all stages of their development. This modification of the peeling method has been used during the summer in the control of the western pine beetle in western yellow pine when burning has become dangerous; and in the control of the mountain pine beetle in lodgepole pine. In treating infested yellow pines a great deal of care must be

exercised in spreading the bark so that it receives the direct rays of the sun, and the use of this method is limited to open stands on slopes receiving the direct rays of the sun and during summer days when the air temperature is above 85° F. In treating infested lodgepole the trees are felled and trimmed and the logs later rolled so that both sides will receive the sun treatment. In fairly open lodgepole stands it is a very efficient method of killing the destructive mountain pine beetle.

4. **Submerging the Infested Logs.**—This method was first advocated by Dr. Hopkins in the control of the bark-beetles, and was expected to be of particular value where the infested trees could be cut and placed in a mill pond.

Recent experiments have shown that submergence requires about six weeks to kill the bark-beetles. If logs are submerged for less time than this, the beetle's development is simply retarded.

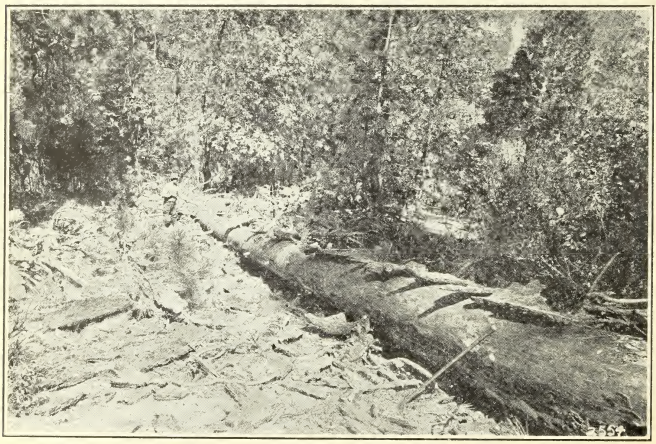

FIG. 8. The solar heat method of bark-beetle control in yellow pine consists of peeling the infested bark from the tree and spreading it so as to receive the full force of the summer sun. While successful under certain conditions it is not as reliable as the burning method and has been largely abandoned in favor of that method, for the control of the western pine beetle. (Photo by J. M. Miller.)

So far this method has not been used in California in the control of forest insects except in an experimental way. It offers possibilities, however, especially in connection with a selective logging program, or in the treatment of infested trees around the lake shores of recreational areas.

5. **Trap Tree Method of Control.**—Since many of the injurious bark-beetles are attracted to felled trees the idea of felling some of the injured, weakened, or noncommercial trees in accessible locations for beetle bait and then destroying them after the beetles have entered the bark of such trees has been advocated. This method

has been used in Europe for many years with apparently beneficial results.

Experience with this method in California has shown that while the felled trap trees will attract many species of bark and wood-boring insects, they will not always attract the beetles which are the most destructive to the healthy trees. Often the destructive beetles will be attracted to the vicinity of the felled trap trees but instead of attacking the trap will attack and kill healthy living trees near by. Moreover, the trap trees have always failed to absorb any large proportion of the beetles on an area and hence can be considered of limited value as a means of control.

6. **Removing the Logs from the Woods.**—This method was first advocated by Hopkins in the control of the Dendroctonus beetles. He recommended that the infested logs be removed from 20 to 50 miles from the forest so that the beetles emerging from them would find no trees to attack.

Often this method has been used unconsciously by logging operators and explains the absence of insect killing around such logging operations. Infested trees have been cut and the logs sent to a mill many miles away; or if the mill is close at hand the logs have been placed in a pond or the slabs burned. This process, together with the removal of beetles in felled green logs which they have freshly attacked, has acted as a control adjacent to these logging operations.

No actual control project has been conducted in California along these lines, but the method is quite workable and satisfactory in connection with any selective logging operation.

WHEN ARE ARTIFICIAL CONTROL METHODS ADVISABLE?

Whenever bark-beetles have become aggressive in the forest and are the responsible agents in the death of large numbers of trees, the application of direct methods of control are advisable provided the value of the timber which can be saved through the work will justify the expense. To apply this general rule requires that certain data be obtained and certain decisions reached.

First, a survey should be made of the infested area and information secured as to the agency responsible for the death of the trees. If the trees are dying primarily because of drought, fire injury or disease, there is obviously little use to control the insects which are the final cause of their death.

Second, if bark-beetles are found to be the primary cause, are they aggressively epidemic or only carrying on their normal activities? In this connection, it has been found that control measures have little effect in reducing the normal loss within the forest, unless the measures are very intensively applied.

Third, what area is affected? How many trees are being killed? And will the value of the timber saved justify the expense of control? In general it may be said that the stumpage value of the timber per M b.m. should be equal to or greater than the cost of treating a similar unit. (Under present conditions the cost of treating will average $4.50 per M b.m.)

And lastly, will it be possible to secure the cooperation of all the owners within a given area, so that the clean-up can cover all of the contiguous infested territory? Small tracts can not be successfully cleaned up if neighboring tracts are left untreated.

HOW TO GO ABOUT ARTIFICIAL CONTROL.

The control of the pine bark-beetles having been decided upon, the next step is the organization of the owners and crews to carry on the work.

Bark-beetle control usually means an organized and cooperative effort on the part of a number of affected owners. To make possible the effective carrying out of control measures a state law was passed in 1923 (see Appendix A) which provides that when the owners of 60 per cent or more of the timberland within any infested zone desire to inaugurate control work, upon petition to and approval of the State Forester, all owners within the zone will be required to clean up their property or have it done at their expense. The timber owners in the vicinity of Arrowhead Lake, San Bernardino County, have recently organized under this law to clean up the infested territory in that vicinity. Over 90 per cent of the owners signed the petition to carry on the work.

For best results, the actual work of felling and treating the trees should be turned over to a well organized crew of workmen under the direction of a man familiar with control methods. Such a crew usually consists of a camp of from ten to thirty men, including a foreman, cook, sawfiler, spotters and laborers.

The spotters mark the trees to be cut and treated. They usually cover the area by running strips, five chains in width, back and forth across the area; locate the infested trees by their distinguishing characteristics; blaze and tag the trees so that they can be easily found by the treating crews; and plot them on map sheets to be used by the treaters in relocating the trees.

The laborers in the camp are usually divided into treating crews of from two to three men. Each crew is assigned to clean up a given area and under the supervision of the camp foreman do the actual work of felling, burning, or peeling.

In western yellow pine forests infested with the western pine beetle a crew will treat on the average from two to three trees per laborer per day and cover 320 acres of infested timberland. Thus in the usual working season of about sixty days, one camp can be counted upon to clean up the infestation on from 15,000 to 20,000 acres.

COST OF CONTROL.

The cost of the work will vary with the type of timber, the method of treatment, the intensity of the infestation, the roughness of the topography, the accessibility of the area, the current cost of labor and various other factors.

For infestations of the western pine beetle in moderately rough country where the burning method has been used, typical control costs for infestations of about 60 trees per square mile have averaged

about $4.50 per M b.m. of timber treated and about 35 cents per acre of forest actually covered with the work.

For mountain pine beetle infestations in sugar pine of less than 10 trees per section, the costs have averaged about $2.30 per M b.m. of timber treated and 10 cents per acre for the territory actually covered.

For mountain pine beetle infestations in lodgepole pine, where large clumps of trees can be rolled together and burned, the usual cost is about 50 cents per tree, $3.50 per M b.m., and $2 per acre, for infestations running around 2000 to 3000 trees to the square mile.

For the treatment of a few scattered trees around summer home sites the costs will probably average somewhat higher.

The peeling and sun curing methods are as a rule slightly more expensive than the burning method.

RESULTS TO BE EXPECTED.

Wherever bark-beetles have been primarily responsible for the death of trees, the application of control measures has resulted in reducing the infestation and has helped to restore the balance in nature. With certain bark-beetles, notably the engraver beetles, control measures have completely stopped the trouble. With the western pine beetle, however, there are so many other factors which are primarily responsible for the death of the trees, that often the reducing of the bark-beetles on the area has not resulted in much improvement in the situation, and trees continue to die from one cause or another even without the assistance of the bark-beetles. For this reason, control should be undertaken only after it has been definitely established that the bark-beetles are the primary cause of the trouble.

On the whole, the artificial control work which has been carried on against the pine-infesting bark-beetles in California has given satisfactory results in reducing aggressive infestations and in saving timber from beetle destruction. Where timber values have been high, the amount of timber saved has more than offset the cost of the work.

THE PINE INSECTS.

To the mind of the layman any small living thing which creeps, crawls or flies is considered to be an insect and is commonly referred to as a "bug." But to the scientist these terms have very special meanings. In the limited sense an insect is a small invertebrate animal with a jointed body, breathing through tracheae and in the adult stage having one pair of antennae and three pairs of legs. This definition excludes the mites and spiders which have four pairs of legs and which are really not insects although closely related to them.

Most of the pine-infesting insects pass through four stages of development. First, an egg is laid by an adult female from which the second

FIG. 9. The larvae or immature stage of various pine insects. All natural size. (A) The yellow pine round-headed bark-borer (*Graphisurus spectabilis* (Lec.)). (B) The pine flat-headed borer (*Melanophila gentilis* Lec.). (C) The red turpentine beetle (*Dendroctonus valens* Lec). (D) The sequoia pitch moth (*Vespamima sequoiæ* Hy. Edw.). (E) A beneficial beetle (*Temnochila virescens* Fabr.). (F) The western pine beetle (*Dendroctonus brevicomis* Lec.). (Original.)

stage, the larva, hatches. The larva is usually soft bodied and worm-like and is commonly referred to as a grub, caterpillar, maggot or "worm." The larva feeds and grows and the final size which it attains is influenced to some extent by the abundance of its food and moisture supply. When maturity is reached the larva transforms to the pupa or resting stage and this in turn changes to the fourth form—the adult insect. A few of the pine insects of lesser importance have what is called an "incomplete metamorphosis" in which they only go

through three forms, the egg, the nymph and the adult. Certain of the scales and plant lice reproduce without eggs.

Practically all of the pine-infesting insects will fall into seven main groups or orders which entomologists recognize as the beetles (*Coleoptera*), the butterflies and moths (*Lepidoptera*), the wasps (*Hymenoptera*), the scales (*Homoptera*), the bugs (*Hemiptera*), the flies (*Diptera*) and the termites (*Isoptera*).

In the following discussion the California pine-infesting insects are discussed in order of their importance in the forest, first by orders, then by families, genera and species. In some cases where the relative importance is debatable the insect has been discussed with its nearest relative.

THE BEETLES.

(*Coleoptera.*)

The beetles are hard-shelled insects and as larvae have biting mouth-parts which they use to chew their way through the plant tissue. They are apparently wingless, but in most cases have wings which are concealed under the hard outer wingcases. During their life they undergo four complete changes, passing from the egg to the larva or grub stage, in which stage the feeding and growth occurs, then to the pupa or resting stage, and finally to the adult or winged form.

The beetles are of great importance in the forest since they include the largest number of species destructive to forest trees, including such harmful groups as the bark-beetles, the ambrosia beetles, the bark-weevils, and the flatheaded borers. Some of the species attack the roots, others the trunks, the limbs, the twigs, the cones and even the needles.

THE BARK-BEETLES.

(*Scolytidæ.*[1])

The bark-beetles are at present the most destructive group of pine beetles with which we have to deal. Several species attack living, healthy trees and bring about their rapid death; others breed in recently felled trees or trees injured from other causes and only at times become destructive to living trees; many others confine their work to the bark of dying or dead trees and assist in their disintegration.

The Pine Beetles.

(*Dendroctonus.*[2])

The *Dendroctonus* beetles (the name means "killer of trees") destroy more mature pine timber than any other bark-beetles found in the United States. There are twenty species which attack forest trees in the United States, of which fortunately only four species are found attacking California pines.

[1] Swaine, J. M. "Canadian Bark-beetles," Bul. 14, Ent. Branch, Dom. Canada Dept. Agr., pt. 2, 1918. "Forest Insect Conditions in British Columbia," Ent. Bul. 7, Div. Ent., Dom. Canada Dept. Agr., 1914.

[2] Hopkins, A. D. "Bark-beetles of the genus *Dendroctonus*," U. S. Dept. Agr. Bur. of Ent. Bul. 83, Part I, 1909.
Hopping, Ralph. "Control of Bark-beetle Outbreaks in British Columbia." Circ. 15, Ent. Branch., Dom. Canada Dept. Agr., 1921.

FIG. 10. When the bark is peeled from a western yellow pine infested with the western pine beetle (*Dendroctonus brevicomis* Lec.), the characteristic winding galleries are evident on the sapwood as well as on the inner surface of the bark. (Original.)

The Western Pine Beetle.

(*Dendroctonus brevicomis Lec.*[1]).

(Figs. 9f, 10, 11.)

Hosts.—Western yellow pine and Coulter pine.

How Destructive.—This is California's most destructive forest insect. Every year thousands of the largest and finest western yellow pine fall as victims to these tiny beetles. The estimated destruction in California alone amounts to 200,000,000 board feet annually or a loss of about a million dollars worth of the highest quality of pine stumpage. This much is called the normal loss since it only represents an annual loss of about one-third of one per cent of the stand, an amount which is offset by the forest increment. Frequently, however, in some locality particularly favorable to the beetles, they build up their numbers until hundreds of the largest trees are killed in every square mile, and the loss for the year may represent as much as ten per cent of the pine stand, which is a very serious drain upon the forest capital.

What It Does.—It kills the trees by boring through the bark and gnawing tunnels through the cambium layer, completely girdling the tree and thus cutting off its sap. Besides attacking and killing the sturdy green trees, it breeds to some extent in windfalls, broken or injured trees, and in the butts and cull logs left from logging operations, or in the main trunk of trees felled in other types of cutting.

It confines its attack to the western yellow pine and Coulter pine, and to the main trunk of the attacked trees. Rarely does it go into tops of less than six inches in diameter, or into the limbs. It seldom attacks trees of less than six inches in diameter and seems to prefer the mature, slow growing trees.

How Recognized.—The adult is a small, brown to black, cylindrical, rather stout beetle with a body somewhat smaller than the ordinary house fly and slightly over one-eighth of an inch in length. The larvæ are small, white, legless grubs less than a quarter of an inch long with small yellow heads. They may be found by slicing half way through the bark of an infested yellow pine, and if the tree is at all heavily infested and the grubs from one-half to full grown they will scatter out like so many grains of rice.

Upon examination of a tree dying from the attack of this beetle, small circular holes about one-sixteenth of an inch in diameter will be noticed in the bark, often in the crevices. A small amount of boring dust will be found in some of these holes and under the adjacent bark scales. Other holes, the holes through which the beetles forced their entry into the tree, will be covered with a small mass of pitch, called a pitch tube. The winding egg galleries will be found in the inner bark and leaving an impression upon the sapwood as well. These egg galleries, which are slightly larger in diameter than the beetle, are filled with "frass" or boring dust and recross each other in such a manner as to form a network of irregular lines. This peculiar type

[1] Webb, J. L. "Western Pine-Destroying Bark-beetle," Bul. 58, pt. 2, Bur. Ent. U. S. Dept. Agr., 1906.
Chamberlin, W. J. "Western Pine Bark-beetle," Bul. 172, Ore. Agr. Coll. Exp. Sta., 1920.

of egg gallery is characteristic of this beetle and might be said to be a copyrighted signature since it is made by no other California beetle.

Seasonal History and Habits.—This beetle is able to kill trees only through the concentration of a large number of individuals upon one tree. A successful attack requires about 15 to 20 parent adults to a square foot of bark or from 2000 to 10,000 beetles to the average tree. After a tree has been selected and attacked by the beetles it dies

FIG. 11. Typical egg galleries made by the parent adults of the western pine beetle (*Dendroctonus brevicomis* Lec.) on the inner surface of the bark of western yellow pine. (Insert) Adults, pupæ and larvæ. All natural size. (Original.)

very quickly, usually within a week or two, although trees attacked in the fall will usually remain green until warm weather the following spring. Very few trees are able to resist the beetles. The parents mine the inner bark, construct their egg galleries and deposit eggs which hatch in about seven days. The grubs feed upon the inner bark and cambium layer of the tree and bore out through the inner bark into

the outer bark. Here they complete their growth, change to the pupa form, then to new adults, and finally emerge from the trees, leaving neat round exit holes in the bark; so that the tree from which many beetles have escaped looks as though it had been peppered with bird shot.

Trees are attacked during June and July from which new broods develop and emerge in August, September and October. These new beetles attack trees during the fall and the brood development continues until stopped by cold weather. The new broods usually pass the winter in the larval stage, although all of the other stages, such as parent adults, eggs, new adults and occasionally pupæ, may be found. They renew activity and continue their development in the spring with the advent of the first warm weather, and emerge as new beetles during June.

Distribution.—Throughout the range of western yellow pine (*Pinus ponderosa*) from lower California north into Oregon, Washington, Idaho, Montana and Western Canada.

Control.—The methods of control are those used in the control of all bark beetles and consist in burning the bark from infested trees before the beetles escape. Placing the bark in the sun is sufficient to kill the beetles provided the air temperature is above 85° F. This method has been used in some localities during the summer when the burning of the bark is not safe.

The greatest good can be accomplished through control measures if they are carried out during the late fall, winter and early spring when the beetles and their broods are all in the bark of the trees. During the summer some beetles are flying at all times, so that many are not destroyed when the bark on a few infested trees is burned or sun cured.

The Mountain Pine Beetle.

(*Dendroctonus monticolæ* Hopk.)

(Figs. 12, 13.)

Hosts.—Sugar pine, western white pine, lodgepole pine, western yellow pine, foxtail pine and probably other pines. Rarely recorded from Engelmann spruce.

How Destructive.—The mountain pine beetle is the second most destructive forest insect in California, being exceeded in destructiveness only by the western pine beetle. It is the most serious enemy of sugar pine, lodgepole pine and western white pine. In Yosemite National Park it has completely killed hundreds of acres of lodgepole pine, and the white weather-beaten trunks of trees form a veritable ghost forest. This killing goes on more or less continuously in lodgepole stands and accounts in part for the short span of life of this tree. Since this tree is not of much commercial value in California, no estimate has been made of the annual destruction.

What it Does.—This beetle prefers living timber, although it occasionally enters the felled trees of sugar pine, white pine and western yellow pine. Like the western pine beetle, the parent adults bore through the inner bark and cambium, slightly scoring the surface of the

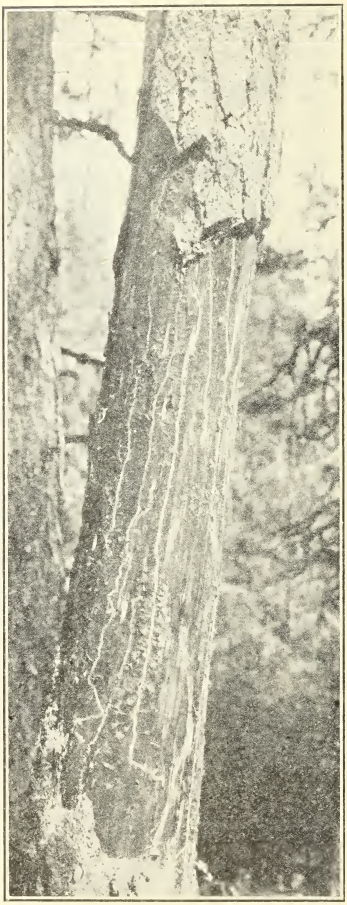

FIG. 12. Mines of the mountain pine beetle on the sapwood of a twelve-inch western yellow pine. Note the long straight egg tunnels and the diverging larval mines ending in round pupal cells. (Original.)

sapwood, but the gallery, instead of winding in an irregular pattern, follows up the grain of the wood after making a short crook at the entrance. The tree does not die from the effect of the adult attack, but only after the larvæ have hatched and have worked out at right angles from the egg gallery, and thus have encircled the tree and cut off the flow of sap.

The beetles attack the trunk of the tree from within a few feet of the ground up to the middle branches. Rarely are the tops or limbs attacked.

How Recognized.—Pitch tubes on the trunk of the trees with reddish boring dust in the crevices of the bark and at the foot of the trees give the first sign of attack. Later the trees can be located by the foliage changing from a normal green to a light greenish yellow and then red.

Upon removing a section of bark infested with these beetles, the characteristic long straight egg gallery filled with boring dust will be noted, and from this gallery branch the larval mines ending in nearly circular pupal cells within the inner bark.

The parent adults will usually be found in the egg galleries. These are small, stout, cylindrical, black beetles about a quarter of an inch long. The larvæ, if full grown, are about the same size as the beetles and are white and legless with small yellow heads. The pupæ are also white, with spines on the abdomen, and may be seen in cells within the inner bark when the bark is removed from the tree.

Seasonal History and Habits.—The overwintering broods emerge in July, August and September, fly and attack other trees. Eggs are laid and most of them hatch and develop to half grown larvæ before the cold winter weather stops their development. Winter is passed in all stages of development except pupæ. On the average there is only one generation a year, but due to the uneven development there is considerable overlapping of the various broods so that at any one time during the summer brood in all stages may be found. Late fall, winter, and early spring is, therefore, the best time to carry on control work.

Distribution.—Throughout the range of lodgepole pine (*Pinus murrayana*) from southern California north into Oregon, Washington, Idaho, Montana and western Canada.

Control.—Considerable control work has been carried out during the past fifteen years in California, directed towards the control of this bark-beetle in sugar pine and lodgepole pine.

The methods employed consisted of either peeling the bark from the trunks of the infested trees, or burning the bark with or without peeling. Recently, very effective destruction of the broods in thin bark lodgepole pine has been secured by felling the trees, trimming the branches and exposing the trunks to the sun's rays. A few hours of exposure during the middle of a bright day is sufficient to kill the brood on at least the upper half of the exposed log. After a day or two of exposure the log is turned and the other half exposed to the sun. This method is very useful where burning is hazardous.

FIG. 13. Section of inner bark surface of western yellow pine showing the typical L-shaped, frass-packed egg gallery and the exposed pupal cells of the mountain pine beetle (*Dendroctonus monticolæ* Hopk.). (Insert) Adult beetles, pupæ and larvæ. All natural size. (Original.)

The Jeffrey Pine Beetle.

(*Dendroctonus jeffreyi* Hopk.).

Host.—Jeffrey pine.

How Destructive.—Through the northern part of the state this is a very destructive enemy of Jeffrey pine; while in the southern part of the state it takes second place to the pine flathead borers. It is aggressive and primary in its attacks upon the trees and succeeds in killing large numbers of Jeffrey pine which are apparently in a healthy condition. However, it is favored in its work by conditions which retard tree growth, such as droughts or defoliations. Like other closely allied species, it rarely attacks felled trees, so does not breed up in slash or windfalls to any extent.

How Recognized.—The work of this beetle is very similar to that of the mountain pine beetle. Reddish pitch tubes form in the crevices of the bark where the beetles force their entrance. From the entrance, the egg gallery takes a slight turn, then proceeds up the tree in nearly a straight line following the grain of the wood. These tunnels are usually two or three feet in length and are packed with boring dust. The eggs are placed in niches along the side of the galleries, and the larvæ, on hatching, work out from the egg gallery across the grain of the wood, cutting off the sap flow and causing the death of the tree.

The larvæ are white, legless grubs. The pupal cells are formed in the inner bark and are exposed to view when the bark is removed.

The adult beetle is a stout, black, cylindrical hardshelled beetle about one-quarter to five-sixteenths of an inch long.

Seasonal History.—Trees are usually attacked during July and August, eggs are laid and the broods reach the larval stage by the time winter sets in, and some of the earlier broods have developed new adults. The parent adults, larvæ and new adults spend the winter under the bark of the trees. In the spring, development continues, and most of the new broods emerge during July and August. Thus ordinarily it requires one year to complete the life cycle. There is, however, considerable overlapping of broods, and a few broods in various stages of development may be found during any part of the year.

Distribution.—Occurs from southern California north to the Oregon line through the range of the Jeffrey pine.

Control—Same as for the mountain pine beetle.

The Red Turpentine Beetle.

(*Dendroctonus valens* Lec.[1]).

(Figs. 9c, 15, 16.)

Hosts.—Probably all pines within its range. Common in western yellow pine, sugar pine, lodgepole pine, Monterey pine, Jeffrey pine, Coulter pine, western white pine, Bishop pine, foxtail pine and digger pine.

[1] Graham, S. A. "The Red Turpentine Beetle in Itasca Park," Paper 392, Jour. series of the Agr. Exp. Sta., Minnesota, 1922.

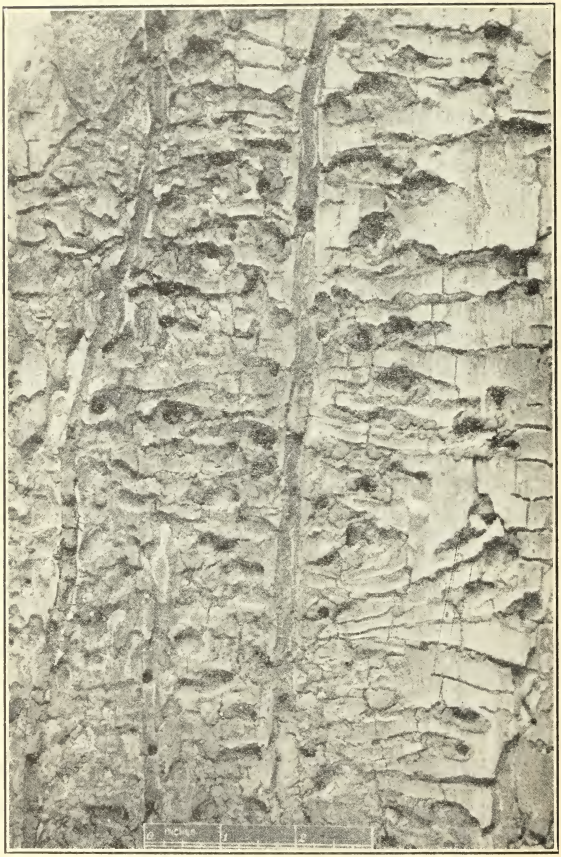

FIG. 14. Inner surface of a section of Jeffrey pine bark showing the straight parent egg tunnels, diverging larval mines and circular pupal cells of the Jeffrey pine beetle (*Dendroctonus jeffreyi* Hopk.). Specimen collected by Dr. E. C. Van Dyke near Lake Tahoe, California. One-half natural size. (Photo by W. C. Matthews.)

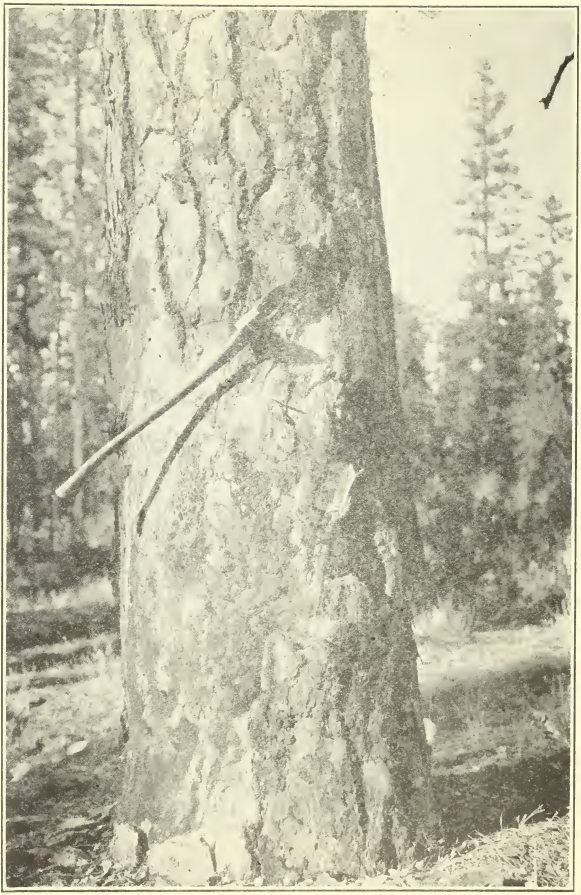

FIG. 15. Bark removed from the base of a western yellow pine to expose the mines and pupal cells of the red turpentine beetle. Large reddish pitch tubes in the crevices of the bark, near the ground, are very characteristic of this beetle's work. (Original.)

How Destructive.—This is probably the most common bark-beetle found by the forester or timber owner. The large pitch tubes which form at the base of the infested trees and the large size of the beetle make it a conspicuous pine enemy.

The adult beetles attack stumps, cut logs and the base of living trees. The larvae eat out cavities in the inner bark and extend their work for several feet up the trunk or occasionally for many feet below the soil in the roots.

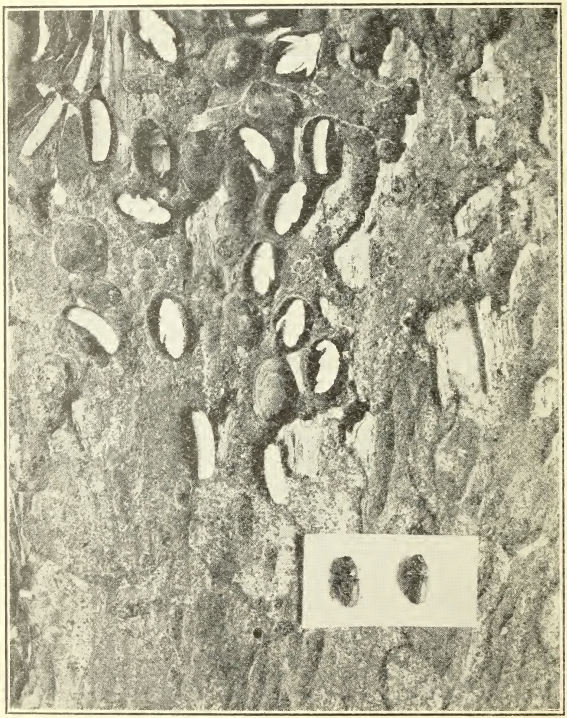

FIG. 16. Larvæ, pupæ, and adults of the red turpentine beetle (*Dendroctonus valens* Lec.) in their excavations on the inner surface of a piece of western yellow pine bark. Natural size. (Original.)

Monterey pines around San Francisco bay region, suffer the most from the attacks of this beetle. The basal portion of the trunk is often completely girdled by the larval excavations and many fine trees succumb to its attacks. On other forest areas, it is not usually capable of killing living trees unless associated with other bark-beetles. For the most part, its work consists in causing basal wounds which burn

out during ground fires and cause the tree to fall, or leave a large basal "fire scar" which greatly weakens the tree.

How Recognized.—This beetle is very easily recognized by its work. Large masses of pitch mixed with reddish borings exuding from circular holes at the base of pines are almost certain evidence of its presence; while under the bark will usually be found the adult beetles and the larvæ working together to excavate a large cavity between the bark and the wood.

The adults are large, stout, light to dark red, cylindrical beetles from one-quarter to three-eighths of an inch in length, and with the entire body sparsely clothed with long hairs.

The larvæ are cylindrical, white, legless grubs with reddish heads, and stout spines on the last abdominal segments. They do not make separate larval mines but feed together and eat out cavities in the inner bark from a few square inches to several square feet in extent. Pupæ form and change to new adults in closely joined cells in the inner bark.

Seasonal History.—The beetles pass the winter under the bark of the tree in the stages of parent adults, larvæ and new adults.

The new adults emerge from the trees during April, May and June and attack new trees and deposit eggs. The eggs hatch within a week or ten days and the larvæ feed until hibernation begins. Some larvæ change to adults in August and September, and a few adults may emerge and attack other trees before winter, but the main part of the brood passes the winter in the larval form.

Due to the overlapping of generations, beetles may be found in all stages of development at any time during the year, except during the winter, when pupæ are rarely found. Flight never occurs in the winter except during warm spells in the southern part of the state.

Distribution.—Throughout the pine forests of North America.

Control.—For park or shade trees, control is best effected by cutting out the beetles with a knife or chisel when the discharge of pitch and frass indicates their presence. Often they can be killed by means of a stout wire inserted into the entrance burrow, provided this is done before the galleries have been extended for more than two or three inches. Prof. R. W. Doane has recently had considerable success in killing the beetles by injecting carbon bisulphid into the galleries.

When control becomes necessary in the forest, it is best effected by peeling the infested bark from the stumps or base of the trees.

The Pine Engraver Beetles.

(*Ips.*)

The engraver beetles of the genus *Ips* are often very destructive to second growth pines and to the tops of mature trees. They probably rank next to the *Dendroctonus* beetles in order of destructiveness to California pines.

Their normal habit is to feed on the cambium of recently felled pines, and they breed very readily and in large numbers in such material as windfalls, snowbreak, logging or road slash. Having increased their progeny in fallen logs and slash, they often emerge in great numbers

and kill adjacent groups of young pines and the tops of mature trees. Usually, however, such epidemic killings of living trees are of short duration and after one season the beetles return to their diet of freshly felled logs.

Some of the species are only of secondary importance, and are rarely found attacking healthy living trees.

How Recognized.—Like the *Dendroctonus* beetles, the adult *Ips* bore between the bark and wood in order to lay their eggs. The male beetle starts the attack and on reaching the cambium constructs an entrance chamber. Several female beetles then join in the work and each constructs an egg gallery radiating from these chambers much like the tines of a fork. These egg galleries cut through the inner bark and slightly score the sapwood. Eggs are laid in niches along the sides of the galleries and the larvæ on hatching feed out from the egg gallery in the inner bark. All of the egg galleries of these beetles are free from boring dust and in this respect can be distinguished from the *Dendroctonus* galleries. Some of the species construct an individual type of gallery by which they may be recognized, other species can not be separated by any distinctive feature of their work.

The external evidence of their work is characterized by boring dust in the crevices of the bark near the entrance and ventilating holes. These beetles rarely form pitch tubes and the boring dust is usually dry and free from pitch. Soon after a tree has been attacked it starts to fade, turns to a silver green, then yellow, and finally sorrel or red.

The adults are small, reddish brown, shiny, cylindrical beetles with a very pronounced cavity at the posterior end with spines along the margin, giving the beetles a truncated appearance.

The larvæ are small white legless grubs with yellow heads, and are very similar to other scolytid larvæ. They are slightly different from the *Dendroctonus* larvæ by being more tapering, thicker at the forward end and slimmer towards the rear.

Seasonal History and Habits.—The beetles usually spend the winter in the adult stage under the bark of the standing trees. With the advent of spring they emerge and attack fallen logs, limbs and tops of green trees, lay eggs and quickly hatch out another brood. From two to five generations develop during the summer, depending upon the altitude, latitude, and the species, since it only requires from 42 to 68 days for the completion of one generation—that is, from first attack to first emergence. There is, therefore, considerable overlapping of the various generations.

Control.—Methods of control are the same as for the western pine beetle. Although peeling the bark will kill the immature stages, there are usually so many adults under the bark and in the limbs that burning is by far the quickest, cheapest and most efficient method of destroying the broods.

There are eleven or more species which infest the California pines. Some of these may be recognized by the character of their work.

The **Monterey Pine Engraver** (*Ips radiatæ* Hopk.[1]) (Figs. 17, 22a) is at times a primary destructive enemy of Monterey pine, but

[1] Trimble, F. M. "Life History and Habits of Two Pacific Coast Bark-beetles." Vol. XVII, No. 4, p. 382, Annals Ent. Soc. Am., 1924

more frequently attacks trees weakened by the red turpentine beetle, or trees which have been recently felled. It also attacks Bishop pine, knobcone pine, lodgepole pine, and according to Hopping is sometimes found in Jeffrey pine. The adult beetles are from 4.5 to 5 mm. in length with parallel sides and have one very prominent spine on the end of each wing cover. The curved or S-shaped egg galleries with

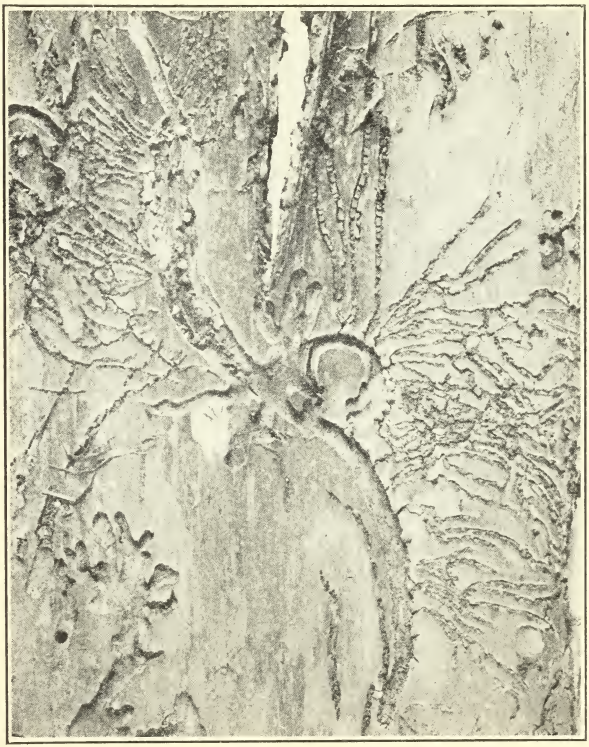

FIG. 17. The curved egg tunnels and the three or four larval mines issuing from each egg niche are characteristic of the work of the Monterey pine engraver *Ips radiatæ* Hopk.). Natural size. (Photo by courtesy of Dr. E. C. Van Dyke.)

three or four larval mines issuing from each egg niche are characteristic features of the work of this species and readily distinguish it from the others.

The beetles over-winter beneath the bark of the trees mostly as new adults, but also in the stages of larvæ and pupæ. In early spring,

and kill adjacent groups of young pines and the tops of mature trees. Usually, however, such epidemic killings of living trees are of short duration and after one season the beetles return to their diet of freshly felled logs.

Some of the species are only of secondary importance, and are rarely found attacking healthy living trees.

How Recognized.—Like the *Dendroctonus* beetles, the adult *Ips* bore between the bark and wood in order to lay their eggs. The male beetle starts the attack and on reaching the cambium constructs an entrance chamber. Several female beetles then join in the work and each constructs an egg gallery radiating from these chambers much like the tines of a fork. These egg galleries cut through the inner bark and slightly score the sapwood. Eggs are laid in niches along the sides of the galleries and the larvæ on hatching feed out from the egg gallery in the inner bark. All of the egg galleries of these beetles are free from boring dust and in this respect can be distinguished from the *Dendroctonus* galleries. Some of the species construct an individual type of gallery by which they may be recognized, other species can not be separated by any distinctive feature of their work.

The external evidence of their work is characterized by boring dust in the crevices of the bark near the entrance and ventilating holes. These beetles rarely form pitch tubes and the boring dust is usually dry and free from pitch. Soon after a tree has been attacked it starts to fade, turns to a silver green, then yellow, and finally sorrel or red.

The adults are small, reddish brown, shiny, cylindrical beetles with a very pronounced cavity at the posterior end with spines along the margin, giving the beetles a truncated appearance.

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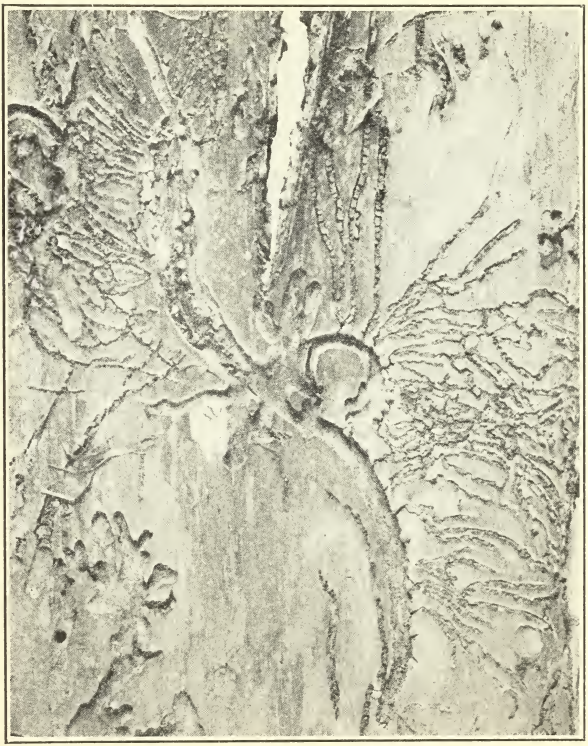

FIG. 17. The curved egg tunnels and the three or four larval mines issuing from each egg niche are characteristic of the work of the Monterey pine engraver *Ips radiatæ* Hopk.). Natural size. (Photo by courtesy of Dr. E. C. Van Dyke.)

three or four larval mines issuing from each egg niche are characteristic features of the work of this species and readily distinguish it from the others.

The beetles over-winter beneath the bark of the trees mostly as new adults, but also in the stages of larvæ and pupæ. In early spring,

the new adults emerge and attack other trees. Eggs are laid and in about nine to ten weeks the new broods have completed their development. There are usually one to two summer generations and a third or over-wintering generation, but the number of generations and the rapidity of development will vary with the seasons and with the altitude and latitude. So far this species has been recorded throughout the coastal range of middle California and in the Sierras from Yosemite north into Idaho.

FIG. 18. Inner surface of pine bark showing the typical galleries of the five-spined yellow pine engraver (*Ips confusus* (Lec.)). (Insert) Adults, pupa and larva. All natural size. (Original.

Ips concinnus (Mann.) is a very similar species which has been frequently confused with *Ips radiatæ* Hopk. It probably attacks only the Sitka spruce.

Ips calligraphus (Germ.) is one of the larger engraver beetles measuring from 4.8 to 6.5 mm. in length and is characterized by having six spines on the end of the wing covers. This is an eastern species but it or a very close undescribed relative was found by F. B. Herbert associated with *Ips confusus* and *Dendroctonus* beetles in western yellow pine and digger pine near Placerville.

The **Five-Spined Yellow Pine Engraver** (*Ips confusus* (Lec.)) (Fig. 18) is the most commonly destructive engraver beetle attacking yellow and sugar pines, western white pine, Coulter pine and Monterey pine. It is less frequently found in single leaf pine, digger pine, lodgepole pine, foxtail pine, and other pines in California. It is particularly destructive to second growth pines and the tops of large trees. It also breeds readily in slash and felled logs, and the broods upon emerging from such material often cause extensive damage to the young pine growth in the vicinity. The adults are small, reddish to black cylindrical beetles about 4.5 mm. in length, with five spines on the posterior margin of the wing covers. The larvæ are small, white, legless grubs somewhat thicker at the front end. The pupæ are shiny white and very active. The egg galleries, which are constructed between the bark and the wood, usually have from three to five nearly straight galleries radiating from a central entrance chamber. The typical form has three galleries in the shape of an inverted Y. These galleries are not packed with boring dust and are usually from 5 to 10 inches long.

The over-wintering adult beetles emerge and make their attacks upon logs or trees during early spring. During warm weather it only requires from 42 to 68 days from the time the egg is laid until a new brood of beetles are again on the wing. Thus from two to five generations of beetles may develop during the summer. In the northern part of the state at an elevation of about 3000 feet there are usually two summer generations which develop in fallen logs and a third or over-wintering generation which develops in standing trees. At lower altitudes and in the southern part of the state there are probably from three to five summer generations. It is generally distributed throughout the western yellow pine belt of the Pacific slope region, and has also been recorded from Arizona. The methods of control are the same as for the western pine beetle. Although peeling the bark will kill the immature stages, there are usually so many adults under the bark and in the limbs that burning is by far the quickest and cheapest method of destroying the broods. Where this species is breeding in logging slash, or in pines cut for roadways or telephone lines, either additional material should be supplied to absorb the emerging broods or the infested material should be burned, in order to protect the young pine growth in the vicinity.

Ips vancouveri Sw. is similar to *Ips confusus* (Lec.) and also has five spines on the posterior end of the wing covers, but is slightly larger. It has been found in lodgepole pine, western white pine, and foxtail pine, but is comparatively rare in California.

The **Large Western Pine Engraver** (*Ips emarginatus* (Lec.)) (Figs. 19, 20) is a primary tree killing species, quite capable of killing trees on its own account, but is more frequently associated with the mountain pine beetle in its attack upon western yellow pine. Occasionally it attacks Jeffrey pine, lodgepole pine and sugar pine. In one case it was found killing a yellow pine, 40 inches in diameter, but usually it attacks small to medium sized trees which have been suppressed.

The adults are dark brown, cylindrical beetles about 6 to 7 mm. in length and are the largest engraver beetles found in California pines.

FIG. 19. Infested western yellow pine barked to show galleries of the large western pine engraver (*Ips emarginatus* (Lec.)). (Original.)

FIG. 20. Galleries on the inner surface of the bark made by the large western pine engraver. Pupæ and larvæ can be seen in their pupal cells. (Insert) Adult beetles and larvæ. Natural size. (Original.)

Their work is characterized by the long, straight, nearly parallel galleries, from 2 to 4 feet in length, which run up and down the tree and connect at different points.

Records taken from the northern part of the state indicate that this species has two generations a year; one generation which develops during the summer and another generation which carries the beetles through the winter. During the summer it requires only 70 days for the beetles to attack a tree, raise a new brood and emerge as new adults. In the southern part of the state there are probably a number of summer generations with considerable overlapping of broods.

FIG. 21. Egg tunnels and larval mines of the smaller western pine engraver (*Ips latidens* (Lec.)) on the surface of western yellow pine sapwood. (Insert) Adults and larvæ. All natural size. (Original.)

It is found throughout the western yellow pine belt of California, Oregon, Washington, Idaho and southern British Columbia.

The **Smaller Western Pine Engraver** (*Ips latidens* (Lec.)) (Fig. 21) for the most part confines its attack to the dead or dying limbs and tops of western yellow pine, sugar pine and digger pine, but also is known to attack Jeffrey pine, lodgepole pine and western white pine. It seldom causes any primary injury, except in the case of digger pines

weakened by mistletoe, when its attacks are often fatal. This is the smallest of the engraver beetles found in California pines (from 2.7 to 3.5 mm. in length). It constructs from two to five short, slightly curved radiating galleries from each entrance chamber, and places its eggs singly in the egg niches. It is found through the pine belt of California, Oregon, Washington and western British Columbia. No control is necessary as it is seldom an aggressive pine enemy.

Ips integer (Eich.) is a large stout species from 4.5 to 6 mm. in length which attacks western yellow pine, lodgepole pine and western white pine, and excavates several longitudinal egg galleries from a large central entrance chamber. It is similar to *Ips plastographus* (Lec.) having four spines on the posterior margin of the wing covers, but is somewhat larger. This is a very common species in the yellow pine forests of the Rocky Mountain region but is rarely if ever found in California.

The **California Pine Engraver** (*Ips plastographus* (Lec.)[1]) (Fig. 22b) prefers to attack the trunks and branches of felled Monterey pine, Bishop pine, and lodgepole pine, but at times also attacks standing trees. It is not often primary in its attacks but usually assists the Monterey pine engraver and the red turpentine beetle in the killing of living trees or trees injured by fire or other causes. The adult beetles are from 4.3 to 5 mm. in length and have four spines on the posterior margin of the wing covers. The work is similar to that of the five-spined yellow pine engraver, the typical form having three egg galleries of from 5 to 15 inches in length issuing from each entrance chamber. It requires from six to eight weeks during the summer for broods to develop from eggs to new adults, emerge and attack other trees. There may be from three to five summer generations and one winter generation, depending upon the locality and season. The winter is usually passed in the stage of young adults under the bark of trees killed during the fall. It is found through the range of the host trees in the coastal range of middle California and in the Sierras and has also been reported as occuring in Arizona and New Mexico.

The **Oregon Pine Engraver** (*Ips oregoni* (Eich.)) (Fig. 23) is very similar in appearance and habits to the five-spined yellow pine engraver with which it is frequently associated in its attack upon western yellow, Jeffrey and lodgepole pines. The adult beetles are slightly smaller and have four spines on the posterior margin of the wing covers, instead of five, but otherwise the work, number of generations, life history, habits and characteristics are much the same as for the five-spined yellow pine engraver. It is widely distributed through the pine belts of New Mexico, Arizona, California, Oregon, Washington, Idaho and British Columbia.

Ips interpunctus (Eich.) is a species very closely related to the Oregon pine engraver, which is listed by Hopping as occurring in lodgepole pine in California.

The Wood-Engravers.

(*Pityogenes.*)

The members of the genus *Pityogenes* are very small brown beetles, very similar to the *Ips*. They usually work under the bark of limbs or in the tops of thin bark pines. They construct a circular entrance

[1] Trimble, F. M. "Life History and Habits of Two Pacific Coast Bark-beetles." No. 4, p. 382, Annal. Ent. Soc. Am. 1924.

FIG. 22. Slab of Monterey pine bark with egg tunnels and larval mines of two pine engraver beetles on the inner surface. (A) The circular egg tunnel with three or four larval mines coming from each egg niche is characteristic of the work of Monterey pine engraver (*Ips radiatæ* Hopk.). (B) The nearly straight forked tunnels with single branching larval mines are made by the California pine engraver (*Ips plastographus* (Lec.)). (Photo by W. C. Matthews from specimens collected at Carmel, California, by Dr. E. C. Van Dyke.)

FIG. 23. Sapwood of a lodgepole pine grooved by the egg tunnels of the Oregon pine engraver (*Ips oregoni* (Eich.)). The egg niches and larval mines are visible along the sides of the tunnels. (Insert) Adults, pupa and larva. All natural size. (Original.)

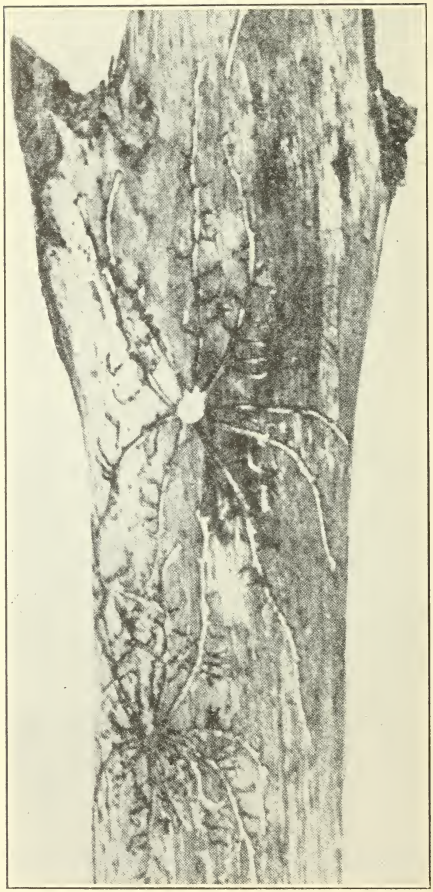

FIG. 24. Limb of western yellow pine showing the central brood chamber and radiating egg galleries of the yellow pine wood-engraver (*Pityogenes carinulatus* (Lec.)). Natural size. (After Hopkins.)

chamber on reaching the cambium, and the females construct numerous radiating egg galleries. Their work differs from that of the *Ips* in that the entrance chamber is usually more circular and the radiating galleries more numerous and stellate; while the egg galleries are usually smaller than most species of *Ips*. They are not an enemy of primary importance in California pines.

The **Yellow Pine Wood-Engraver** (*Pityogenes carinulatus* (Lec.)) (Fig. 24) usually attacks the trunks, limbs and twigs of injured, dying or recently felled western yellow pine, so can not be considered as a primarily destructive insect. It has also been found by J. E. Patterson attacking white bark pine and is recorded by Hopping from Jeffrey and lodgepole pines. The adults are small slender, reddish brown beetles about 3 mm. in length. The males have two prominent curved spines on the posterior end. They excavate numerous radiating galleries from a large central chamber. The galleries are mostly in the inner bark but also score the sapwood. It is found throughout the Sierras north into Oregon.

The **Lodgepole Pine Wood-Engraver** (*Pityogenes knechteli* Sw.) is a stout species about 2.8 mm. in length and is very commonly found associated with *Ips* under the thin bark of lodgepole pines throughout the range of this tree.

Pityogenes fossifrons (Lec.) is a rare species which has been found by Hopping in western white pine, yellow pine and lodgepole pine in California.

The Twig Beetles.

(*Pityophthorus.*)

The twig beetles are very small, cylindrical, brown bark-beetles which confine their work to boring under the bark and in the pith of twigs. They are often very abundant in the branches and twigs of dead, dying, or recently felled trees, but seldom attack the twigs of healthy ones. Under some conditions they may assist other beetles in killing trees. There are a great many different species, which are all so similar that the layman should not attempt to separate them.

The typical gallery of the adults consists of a more or less circular chamber with small radiating mines and prominent egg niches. Several females work out from a single nuptial chamber, constructing their galleries lengthwise with the stem.

No control has ever been attempted, nor do they do enough damage so that control would seem advisable. If they are troublesome to garden or shade trees, pruning the infested branches and burning the twigs might be of some benefit.

Seven species have so far been described from California pines and there are probably many more as yet undescribed. *Pityophthorus confertus* Sw. (2 mm. long) attacks twigs and dead cambium of dying and felled lodgepole pine, western yellow pine, sugar pine and knobcone pine, and is also reported by Hopping from Jeffrey pine and western white pine. *Pityophthorus confinis* Lec. (3 mm. long) attacks the dying limbs and twigs of western yellow pine and Jeffrey pine, and according to Hopping also attacks sugar pine. It ranges through California, Oregon, Washington and Idaho. *Pityophthorus serratus* Sw. was described from specimens collected by Hopping from yellow pine limbs in Siskiyou County. *Pityophthorus atratulus* (Lec.) (*P. puncticollis* (Lec.)) (Fig. 25) attacks the twigs of dying or felled Monterey pine, knobcone pine, lodgepole pine and probably other pines throughout the western states. *Pityophthorus tuberculatus* Eich. (1.7–2.3 mm. long) commonly attacks the twigs of western yellow pine, sugar pine, lodgepole pine and digger pine. *Pityophthorus carmeli* Sw. was named from material collected by Van

Dyke in Monterey pines near Carmel. *Pityophthorus torreyana* Sw. (2.5 mm. long) was named from specimens collected by the author from the twigs of Torrey pine near San Diego.

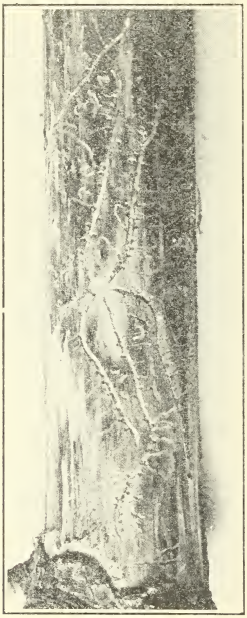

FIG. 25. Typical gallery of a twig beetle (*Pityophthorus atratulus* (Lec.)) marking the sapwood of a Monterey pine limb. Natural size. (Original.)

THE CONE BEETLES.

(*Conophthorus*[1].)

This is a group of small black scolytid beetles very closely allied to the twig beetles (*Pityophthorus*) which for the most part confine their work to pine cones and the supporting stems. Five species, which have been described by Hopkins, are to be found infesting the cones of California pines.

The **Yellow Pine Cone Beetle** (*Conophthorus ponderosæ* Hopk.) commonly attacks western yellow pine cones through California and Oregon but occasionally is found in Jeffrey pine cones. The **Sugar Pine Cone Beetle** (*C. lambertianæ* Hopk.) (Fig. 26) commonly kills sugar pine cones but also is found in western white pine cones in California and Oregon. The **Monterey Pine Cone Beetle** (*C. radiatæ*

[1] Miller, J. M. "Cone Beetles: Injury to Sugar Pine and Western Yellow Pine." Bul. 243, U. S. Dept. Agr., 1915. "Insect Damage to the Cones and Seeds of Pacific Coast Conifers." Bul. 95, U. S. Dept. Agr., 1914.

Hopk.) is found in Monterey pine cones, in the native groves of this tree at Monterey. The **Single Leaf Pine Cone Beetle** (*C. monophylla* Hopk.) attacks cones of the single leaf pine in southern California. The **Beach Pine Cone Beetle** (*C. contortæ* Hopk.) attacks cones of beach pine in the northwestern corner of California.

FIG. 26. Immature sugar pine cones killed by the sugar pine cone beetle (*Conophthorus lambertianæ* Hopk.). Natural size. (After Miller.)

THE AMBROSIA OR TIMBER BEETLES[1].

How Injurious.—This is a group of small, stout, dark brown or black beetles which construct "pin holes" or "shot holes" deep into the sound sapwood and heartwood of forest trees. They are called "ambrosia beetles" because the larvæ do not feed upon the wood, but upon a fungous growth or "ambrosia" which their parents propagate for them in the galleries. The holes in the wood and the dark stain caused by the fungus reduces the value of the timber or renders it worthless, sometimes even for stove wood. As a rule trees dying from other causes and with fermenting or "sour sap" are chosen for attack, but occasionally the beetles will attack healthy trees. Felled trees, saw logs, green lumber, stave bolts and wine casks are also favorite hosts.

How Recognized.—Their work is characterized by the pin holes of uniform size penetrating the sapwood or heartwood of the trees and often branching in various directions (Fig. 27), these galleries being free from boring dust or other refuse, and by the white fine boring dust which is cast out of the galleries and collects in the crevices of the bark around the attacked trees.

Control.—Since these beetles rarely attack living trees there is no occasion to attempt their control in the forest. In order to prevent damage to forest products, felled material should be promptly removed from the forest.

[1] Hubbard, H. G. "The Ambrosia Beetles of the United States." U. S. Dept. Agr., Bull. No. 7 n.s., p. 1-30, 1897.

The **Western Pine Wood-Stainer** (*Gnathotrichus retusus* (Lec.)) (Fig. 27) is the species commonly found mining the sapwood and heartwood at the base of western yellow pines and sugar pines which are dying from bark-beetle attacks or attacking felled logs. The galleries usually enter the sapwood for a short distance, then branch on a horizontal plane, with one long side tunnel often following the annual rings about an inch inside of the wood. The egg niches are constructed above and below these main galleries, each larva inhabiting an individual "cradle." The fine white dust at the base of the trees and in the crevices of the bark is a characteristic sign of their presence. Hopping[1] records this species as also attacking Jeffrey pine, lodgepole pine

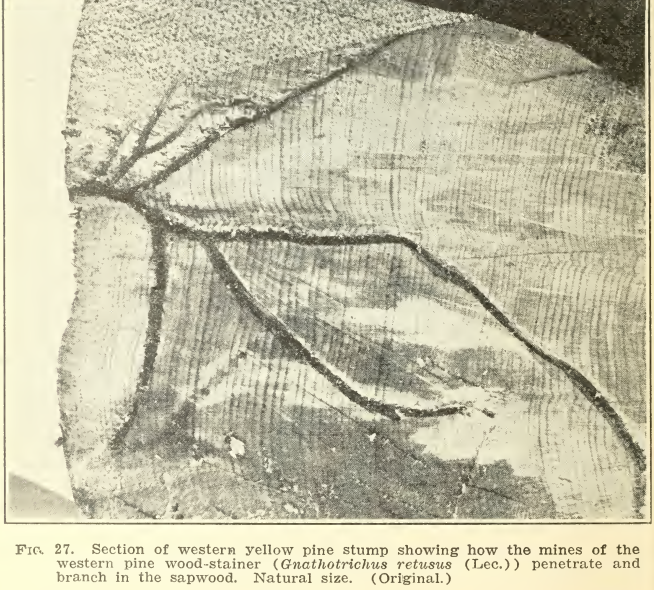

FIG. 27. Section of western yellow pine stump showing how the mines of the western pine wood-stainer (*Gnathotrichus retusus* (Lec.)) penetrate and branch in the sapwood. Natural size. (Original.)

and Douglas fir. It is widely distributed through the forests of the Pacific slope. *Gnathotrichus sulcatus* (Lec.) commonly attacks firs and spruces, but Hopping[1] reports having found it in western white pine.

The **Yellow Pine Shot-Hole Borer** (*Xyleborus scopulorum* Hopk.) is a small light brown beetle from 2.5–2.85 mm. in length which is very closely allied to the Lesser Shot-Hole Borer *Xyleborus xylographus* (Say.). It is frequently found breeding in the dead sapwood of bark-beetle killed western yellow pine and Coulter pine and feeding upon fungous growth.

[1] Hopping, R. "Coniferous Hosts of the *Ipidæ* of the Pacific Coast and Rocky Mountain Regions." Can. Ent. Vol. LIV, No. 6, June, 1922, p. 128.

Bark-Beetles of Secondary Importance Found In California Pines.

Hylurgops subcostulatus (Mann.) is a small rusty brown beetle about 4 mm. in length which excavates a short longitudinal, slightly curved gallery in the inner bark at the base of pines killed by the bark-beetles; especially where the sap has produced a sour condition. Trees are attacked and eggs laid during May and June. The larvæ upon hatching work out in all directions without making clearly differentiated mines. Pupation occurs in the inner bark and the new adults develop and emerge in August and September, and another generation then develops which passes the winter under the bark of newly infested trees as larvæ and new adults. While very common in western yellow pine it is also found in sugar pine, Jeffrey pine, western white pine, lodgepole pine, and probably other pines within its range, which extends from British Columbia south through the western United States into Arizona and New Mexico. *Hylurgops rugipennis* (Mann.) is a narrow reddish beetle about 5 mm. in length, which is widely distributed through the Pacific slope region and is commonly found attacking injured, dying and felled spruce, fir, Douglas fir, and pines. While showing a preference for spruce and fir it has been reported from Bishop pine, shore pine, western yellow pine, sugar pine, western white pine, lodgepole pine, Monterey pine and foxtail pine. A similar species, *Hylurgops porosus* (Lec.), has been reported as occurring in white pine and Monterey pine in California. Another species, *Hylurgops leconteï* Sw., will probably be found in western yellow pine and lodgepole pine. A species closely allied to the eastern *Hylurgops pinifex* (Fitch.) has been recorded by Hopping as occurring in California in foxtail pine and lodgepole pine; and also has been found by J. M. Miller in Jeffrey pine and limber pine. These last three species are not as yet well recognized.

Pseudohylesinus sericeus (Mann.) is a small brown bark-beetle which is reported as a secondary enemy attacking injured, dying and recently felled shore or beach pine, in the coast region of northern California and north into Alaska.

Members of the genus *Hylastes* Er. are small, elongate, dull black beetles which are found under the bark of dying and dead pine, and other coniferous trees. Three or more species are occasionally found in California pines. *Hylastes macer* Lec. is said to attack Jeffrey pine. *Hylastes nigrinus* (Mann.) has been reported from western white pine and Monterey pine.

Carphoborus radiatæ Sw. is a small reddish black beetle 2 mm. in length which is infrequently found in Monterey pine and lodgepole pine. *Carphoborus simplex* Lec. is a similar small bark-beetle found occasionally in digger pine, western yellow pine and sugar pine.

Dolurgus pumilus (Mann.) is a very small bark-beetle usually found associated with species of *Ips* or *Dendroctonus* in the limbs or trunks of pines and spruces. Besides spruce it has been found in Monterey pine, Bishop pine, western white pine and ranges from Monterey north into Alaska.

Orthotomicus ornatus Sw. is a very small cylindrical bark-beetle resembling the *Ips*. It is frequently found under the thick bark of western yellow pine and Jeffrey pine in small mines intermingling with those of the pine beetles and has been recorded by Hopping from lodgepole pine.

THE FLAT HEADED BORERS.[1]

(*Buprestidæ.*)

How Destructive.—The flat-headed or "metallic" borers are a very destructive group of insects attacking California pines. Some of the species attack and, by mining under the bark, kill healthy trees. Others bore into the inner bark and outer wood of trunks, branches and twigs of weakened or dying trees; while others breed only in dead or recently felled trees and make oval winding wormholes through the wood, which seriously reduce the value of the timber for lumber purposes.

[1] Burke, H. E. "Flat-headed Borers Affecting Forest Trees in the United States." U. S. Dept. Agr. Bul. No. 437, 1917.
"Western *Buprestidæ*." Jour. Econ. Ent. 10, No. 3, p. 325, 1917; 11, No. 2, p. 209, 1918. Proc. Ent. Soc. Wash., 22, No. 4, p. 72, 1920.
Chamberlin, W. J. "*Buprestidæ* of Northern California." Ent. News, 28, pp. 129, 156, 1917.

How Recognized.—The flat-headed borers differ from the bark beetles in that the parent adults do not burrow beneath the bark to lay their eggs but lay them on the surface. The grubs upon hatching do the burrowing and construct long, winding, flattened, oval mines either in the bark, the wood, or in both. These mines gradually increase in size with the growth of the grubs, and end in an elongate, oval pupal cell. The grubs are the form usually found in the trees and can be recognized by their long, slender, white, horse-shoe nail shaped, legless bodies, and broad flattened heads.

The adult beetles are generally much larger than the bark-beetles and can be recognized by their flat shape and bright metallic luster. Although they are often seen in the woods resting upon the bark of trees or on logs, they are not often associated in the mind of the layman with the grubs which do the damage in the trees.

Seasonal History.—The adult beetles may be found flying, mating and laying eggs upon the trees during the early spring and summer. The eggs soon hatch and the larvæ burrow under the bark and commence to feed upon the bark or wood tissues. Growth continues until fall when activity ceases with the advent of cold weather. The winter is usually passed in the larval stage, although some larvæ may pupate in the fall and pass the winter in the adult stage. Some species require one, two, or even three or more years to complete their growth.

Control.—The only control methods applicable to tree-killing species under forest conditions are those used in the control of bark-beetles. Of these methods, the burning method is preferable since some species are not killed by exposure to the sun when protected by bark or wood.

There are a large number of species which bore into the wood of California pines, but only a few which attack the living trees.

Bark-Boring Buprestids.

The beetles of the genus *Melanophila*[1] are bark-borers in the trunks, tops and limbs of healthy, injured, or dying trees. The larvæ usually pupate in the bark, but in thin bark trees sometimes enter the wood to pupate. They include the only tree-killing species of flat-headed beetles found in our western pines.

The **Pine Flat-Headed Borer** (*Melanophila gentilis* Lec.) (Figs. 9b, 28, 29a). Through the Sierras this beetle is responsible for the death of many pines, particularly those growing on rocky slopes or on soils where the moisture is insufficient. The adult beetles are about a half inch in length and are a bright bluish-green. The larvæ are white legless grubs about an inch in length. They work under the bark, making flat winding mines which are packed with arc-like layers of sawdust and excrement. On reaching maturity, the larvæ work out into the outer bark and pupate in oval cells close to the bark surface. They commonly attack western yellow pine and sugar pine, but have also been recorded from Jeffrey pine and western white pine, and may be found in other pines throughout the western states.

Eggs are laid in the early spring or summer and the larvæ develop and feed in the inner bark until fall when they reach maturity. Winter

[1] Burke, H. E. "Biological Notes on Some Flat-headed Bark-borers of the Genus *Melanophila*." Jour. Econ. Ent., Vol. 12, p. 105, Feb., 1919.

s passed by the full grown larvæ in the bark. In the spring they pupate and emerge as adults, thus repeating the attacks and the life cycle. The larvæ of this species like a great deal of heat so that it is impossible to kill them by the sun curing method of laying unpeeled

a

b

FIG. 28. Inner surface of western yellow pine bark, showing the larval mines of the pine flat-headed borer (*Melanophila gentilis* Lec.). (a) Adult beetles natural size. (b) Larvæ natural size. (Original.)

gs in the sun. The only satisfactory way is to peel the trees and burn ne bark, as in the case of the western pine beetle.

Melanophila californica Van Dyke is a greenish bronze beetle one-half inch length. Like its near relative the pine flat-headed borer this beetle is very estructive to healthy, weakened or slightly injured trees. In southern California is a very common enemy of the Jeffrey pine. It has also been found attacking

western yellow pine, Monterey pine, knobcone pine, digger pine and Coulter pine *Melanophila intrusa* Horn. is a bronze beetle 8 mm. in length which commonly attacks limbs and small dying trees of western yellow pine, but also is found in Monterey pine, knobcone pine and sugar pine. *Melanophila consputa* Lec. is a nearly black species with small yellow spots. It commonly attacks fire injured weakened, injured or dead western yellow pine, knobcone pine, lodgepole pine and Torrey pine. *Melanophila acuminata* (De G.), another black species 10–12 mm in length, has been found in lodgepole pine in trees badly scorched by fire.

Wood-Boring Buprestids.

The larvæ of the genus *Buprestis*[1] are wood-borers in the stumps and trunks of injured, dying and dead conifers. The Golden Buprestid (*Buprestis aurulenta* L.) (Fig. 29b) is one of the most beautiful beetles found in the woods. The adults are a bright bluish green richly marked with gold and red and are from one-half to

Fig. 29. The adults of various pine flat-headed borers. (a) the pine flat-headed borer (*Melanophila gentilis* Lec.). (b) The golden buprestid (*Buprestis aurulenta* L.). (c) The placid buprestid (*Chrysophana placida* (Lec.)). (d) The sculptured pine borer (*Chalcophora angulicollis* (Lec.)). (e) The common anthaxia (*Anthaxia æneogaster* (Lap.)). (f) A pine chrysobothris (*Chrysobothris monticola* Fall). (g) A pine dicerca (*Dicerca tenebrosa* (Kirby)). All natural size. (Original.)

three-quarters of an inch in length. The larvæ bore in the old wood of most California pines and are particularly attracted to fire scars or exposed pitchy wood. It has been reared from western white pine, sugar pine, western yellow pine, Jeffrey pine, lodgepole pine, knobcone pine, digger pine, Monterey pine, Coulter pine, and other conifers. The larvæ of *B. læviventris* (Lec.) work in the dry or rotting dead wood of western yellow pine, lodgepole pine, digger pine, sugar pine, single leaf pine, Monterey pine, Jeffrey pine, knobcone pine, and other conifers. At times it

[1] Burke, H. E. "Biological Notes on some Flat-headed Wood-borers of the Genus *Buprestis*." Jour. Econ. Ent., Vol. 11, p. 334, June, 1918.

is beneficial in hastening the decay of stumps on cleared land. The adults are large brownish black beetles about three-quarters of an inch in length, with yellow marking. *B. connexa* Horn. is a rare species which probably breeds in Jeffrey pine and western yellow pine on the east slope of the Sierras. The adults are a brilliant green and black and about five-eighths of an inch in length. *B. adjecta* (Lec.) is a rare high mountain species which has been bred from western yellow pine. It probably also attacks Jeffrey pine and lodgepole pine, as well as some of the firs. The adults are brilliant bronze or green beetles about five-eighths of an inch in length. *B. maculativentris* Say var. *rusticorum* (Kirby), is greenish black and about three-quarters of an inch in length. While normally a fir feeder it has been bred from knobcone pine.

The larvæ of the genus *Anthaxia* are bark-borers in the trunks and branches of injured, dying and dead shrubs and trees. The **Common Anthaxia** (*Anthaxia aucogaster* (Lap.)) (Fig. 29e) is a small bronze beetle (4.5 mm. in length) the larvæ of which bore under the bark of dead limbs of western yellow pine, knobcone pine, digger pine, Monterey pine and sugar pine, as well as a great number of other trees and shrubs. It ranges throughout North America.

The larvæ of the genus *Chrysobothris* are bark and sapwood borers in the roots, stumps, trunks, tops and branches of injured, dying and dead shrubs and trees. None of them are of importance as enemies of living trees. A few of the more common pine feeders are as follows: *Chrysobothris caurina* Horn. has been bred

FIG. 30. Larva of a yellow pine twig buprestid (*Chrysobothris contigua* Lec.). Natural size. (Photo by J. E. Patterson.)

from dead limbs and trunks of western yellow pine, lodgepole pine, knobcone pine and Monterey pine. Common through the northern part of the state. *C. monticola* Fall (Fig. 29f) has been reared from dead limbs of digger pine, Monterey pine and western white pine. *C. contigua* Lec. (Fig. 30) has been found attacking old wood and dead limbs of small trees of western yellow pine, and knobcone pine. *C. dentipes* (Germ.) breeds in the dead limbs and trunks of small trees of western yellow pine and probably other western pines. *C. dolata* Horn. has been bred from dead limbs of western yellow pine. It is said to attack lodgepole pine, sugar pine and Jeffrey pine. *C. californica* Lec. has been found in the dead sapwood of western yellow pine. *C. falli* V. D. has been bred from western yellow pine in the Sierra region. It is said to attack Jeffrey pine and lodgepole pine.

The **Placid Buprestid** (*Chrysophana placida* (Lec.)) (Fig. 29c) is the only member of this genus. It is a small green or greenish red beetle less than one-half inch in length and has the singular habit of boring through the hard dry cones of knobcone pine and western yellow pine. It also bores in the dead limbs, branches, trunks and stumps of practically all western pines and firs and has been noted from western white pine, sugar pine, western yellow pine, single leaf pine, digger pine, Jeffrey pine, lodgepole pine and knobcone pine.

The **Sculptured Pine Borer** (*Chalcophora angulicollis* (Lec.)) (Fig. 29d) is the largest flat-headed borer found attacking California pines. The larvæ bore in the wood of stumps and trunks of injured, dying or dead western yellow pine, lodgepole pine, sugar pine, digger pine, Jeffrey pine and some of the firs. The adults are dark

metallic brown to black, and over an inch long, and often startle the forester b buzzing away from their resting place on a pine trunk with the noise of a miniatur aeroplane.

The larvæ of the genus *Dicerca* are wood-borers in the stumps, trunks an branches of injured, dying and dead shrubs and trees. *Dicerca tenebrosa* (Kirby (Fig. 29g) breeds in dead limbs and trunks of lodgepole pine, western pine, yello pine, Jeffrey pine, and other conifers.

THE ROUND-HEADED BORERS.

(*Cerambycidæ*[1].)

This is a very large family of beetles which throughout the Unite States causes damage to forests and forest products estimated at mil lions of dollars. They are called "round-headed" borers on accoun of the general shape of the larvæ or grubs; and are often called "long horned" beetles because of the characteristically long antennæ of many of the adults.

The California pine feeding members of this family for the most par bore under the bark, into the sapwood and heartwood of dead, dying or felled trees and riddle the wood with their tunnels. Some specie follow the more destructive bark-beetles and are such voracious bark feeders that they destroy the food supply of the bark-beetles and limit the development of the latter; thus acting in the capacity of beneficia insects. Other species breed in the dry limbs and twigs of dying o dead trees; many feed in the wood of the main trunk; and several species feed only in rotten or decaying wood and hasten its disintegration. None of the California pine species can be considered as primarily destructive to living trees. Their greatest damage is in mining the wood and ruining the timber for commercial purposes. The only practical methods of control consist in the prompt removal of freshly cut logs from the woods, placing the logs in mill ponds, or peeling the logs so as to prevent attack. The following species have been found attacking California pines.

Bark-Boring Cerambycids.

Some of the California round-headed borers confine their work to the bark and cambium layer and do not riddle the wood with their mines. These, however, are not primary in their attack but follow the tree killing beetles and feed on the dying bark.

The larvæ of the genus *Graphisurus* (*Acanthocinus*) are the common white grubs or "fish worms" (Fig. 31b) found under the bark of trees recently killed by bark-beetles. They are strictly bark feeders and rarely enter the wood except to form pupal cells in very thin bark trees. Eggs are laid in the crevices of the bark or in bark-beetle ventilating holes, and the larvæ feed in the inner layers of bark, often consuming so much of it as to starve out the bark-beetle broods. The pupal cells are formed in or under the bark and the adults emerge through oval holes chewed by them through the outer bark layers. The full development from egg to adult usually takes a single season. The **Yellow Pine Round-Headed Bark-Borer** (*Graphisurus spectabilis* (Lec.)) (Figs. 9a, 31) is a very common secondary bark-borer in western yellow pine following closely upon the attack of the western pine beetle. The large white grubs are very conspicuous between the bark and wood of such trees and are often mistaken by the layman for destructive species. The adult is a large mottled gray beetle about three-quarters of an inch in length and with very long antennæ. Some of the males have feeders over three inches in

[1] Craighead, F. C. "North American *Cerambycid* Larvæ." Bul 27, n. s. (Ent. Bul. 23), Dom. Can. Dept. Agr., 1923.

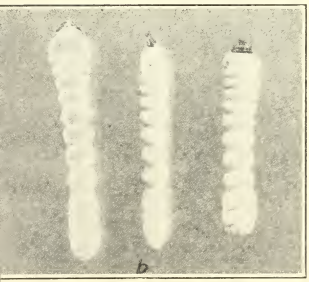

FIG 31. The **Yellow Pine Round-Headed Bark-Borer** (*Graphisurus spectabilis* (Lec.)). (a) Larva feeding through inner surface of western yellow pine bark and destroying the mines of the western pine beetle. (b) Full grown larvæ. (c) Adults, male and female. All natural size. (Original.)

length, while the females have feelers only slightly longer than their bodies. They are found throughout the state in yellow pine and probably other pines. The **Oblique Round-Headed Bark Borer** (*G. obliquus* (Lec.)) is a smaller gray beetle with zig-zag black markings on its back and is about half an inch in length. The larvæ are commonly found in western yellow pines which have been killed and abandoned for over six months by the western pine beetle. It has been reared from both western yellow pine and Jeffrey pine and is found throughout the Sierras.

The **Ribbed Pine Borer** (*Rhagium lineatum* Oliv.)[1] is a gray beetle about one-half to three-quarters of an inch in length with brownish markings and a

FIG. 32. The **Sawyers.** (a) Adults of the **Spotted Pine Sawyer** (*Monochamus maculosus* Hald.). (b) Adults of the **Black Fir Sawyer** (*Monochamus oregonensis* Lec.). All natural size. (Photo by J. E. Patterson.)

prominent spine on each side of the prothorax. The larvæ are often found working under the bark of dead pines and other conifers, except the cupressine trees. They construct a very typical oval pupal cell between the bark and wood or slightly impressed in the sapwood, which is lined with long shreds of excelsior-like shavings.

[1] Hess, Walter N. "The Ribbed Pine Borer." Mem. 33, Cornell Univ. Agr. Exp. Sta., May, 1920.

ney have been found breeding in western yellow pine, digger pine and Monterey ne, and have been taken on lodgepole pine, Jeffrey pine and knobcone pine in which ey no doubt breed. They are found throughout the state.

Wood-Boring Cerambycids. In Unseasoned Wood.

A number of wood-boring Cerambycids are attracted to trees recently lled by fire, insects or disease; trees broken down by wind and snow, unpeeled logs left in the woods. Eggs are laid in the crevices of e bark, and the larvæ upon hatching bore beneath the bark and then to the sapwood and heartwood, completely riddling the freshly killed nber with the worm holes, and rendering it unfit for lumber. These ecies cause the most damage of any of our western pine feeding und-headed borers. The best method of preventing injury is through e prompt utilization of the killed trees, or placing the logs in the mill nd for six weeks or more, or peeling logs which are to be left in the oods for any length of time.

The **Sawyers.** These are the larvæ of the genus *Monochamus* (*Monohammus*)[1] ne species of which cause tremendous damage to freshly killed timber in different rts of the United States. The stout, white legless larvæ bore into the sapwood d heartwood and throw out copious amounts of coarse white boring dust which llects on the ground beneath their excavations. At present there is considerable nfusion between the species. The **Spotted Pine Sawyer** (*Monochamus maculosus* ald.) (Fig. 32a) is a mottled, brownish beetle about an inch in length, and th very long antennæ. It commonly breeds in lodgepole pine and Douglas fir d is less frequently found in yellow pine, on Jeffrey pine and other pines. It curs from middle California north into Oregon. *M. obtussus* Csy. is very similar the above and questionably distinct. The adults are also found on lodgepole ne and western yellow pine, but have been actually reared from knobcone pine d Douglas fir. The **Black Fir Sawyer** (*Monochamus oregonensis* Lec.) (Fig. b) is a large, stout, black beetle about an inch in length and with very long feelers. commonly attacks the firs but has also been reported from lodgepole pine and stern white pine. The adults are frequently found on lodgepole pine logs.

The larvæ of the genus *Liasemum* (*Asemum*) bore winding, traverse galleries tween the bark and the wood of living, injured, or dying trees; then turn their rrows into the sapwood and occasionally penetrate to the heartwood. The life cle appears to be completed in either one or two years. The **Mokelumne Pine rer** (*Liasemum mokelumne* Csy.) (Fig. 33) is a very common borer in western llow pine, and is often found mining the sapwood of trees recently abandoned by rk-beetles. The adults are small brown beetles about half an inch in length, with mparatively short antennæ. They are found throughout the Sierras and north o Oregon. The **Douglas Fir Round-Headed Borer** (*Liasemum nitidum* ec.)), which is very similar to the above, has been found breeding in Monterey ne and digger pine, and is frequently taken resting on the trunks of other pines in ich it probably breeds.

The **Black Spruce Borer** (*Asemum atrum* Esch.) is a small black beetle about lf an inch in length which commonly feeds in the sapwood of dying Douglas fir. e larvæ have been found mining the sapwood of lodgepole pine and western llow pine and are frequently found on Jeffrey pine, in which it may also breed.

Criocephalus asperatus Lec. is a large slender dark brown to black beetle about inch in length and with antennæ less than half as long as the body. The adults commonly found flying about lights but the larval habits are not well known. It obably feeds in the wood of various coniferous trees including the pines. *Crio-halus productus* Lec. is very similar to the above only smaller, being about three-arters of an inch in length. The larvæ have been found boring in the sapwood l heartwood of western yellow pines recently killed by bark-beetles. It is widely tributed.

[1] Hopping, Ralph. "A Review of the Genus *Monochamus* Serv." Can. Ent., Vol. II, No. 11, p. 252, November, 1921.

FIG. 33. Larval mines of the Mokelumne pine borer (*Liasemum mokelumne* Csy.) marking and entering the sapwood of western yellow pine. (Insert) Adult beetles. All natural size. (Original.)

Wood-Boring Cerambycids. In Seasoned Wood.

Some of the round-headed borers prefer to feed on dry seasoned wood and at times cause considerable damage to wood even after it has been converted into lumber.

Species of the genus *Callidium* are in the larval stage small bark and wood-boring grubs which usually attack the branches of dying or dead trees. The **Black-Horned Pine Borer** (*Callidium antennatum* Newm.) is a dark, bluish-purple beetle about half an inch in length. The larvæ bore between the bark and into

Fig. 34. The black spruce borer (*Ascoma atrum* Esch.). Adult beetle and larval mines in lodge-pole pine. Natural size. (Original.)

the wood of pines, cedars, firs and spruces. They enter the wood to pupate and form a long pupal cell in the sapwood parallel with the grain of the wood. Recently the mines of this beetle have caused considerable damage to finished western yellow pine edgings at a mill yard in Lassen County. The adults of *Callidium hirtellum* Lec. are a little more than a quarter of an inch in length and yellow to nearly black in color. The larvæ are commonly found boring through the dry dead twigs of western yellow pine.

Certain species of the genus *Pogonocherus* feed in the dead twigs of pines. *Pogonocherus californicus* Schffr. has been bred from the wood of digger pine

and is reported by Van Dyke as living in western yellow pine. It is a small gray hairy beetle about a quarter of an inch in length. *Pogonocherus propinquus* Fall has also been reported by Van Dyke as occurring on western yellow pine.

The **Round-Headed Cone Borer** (*Paratimia conicola* Fisher) has the unique habit of boring tunnels through the hard dry pith and scales of knobcone pine cones. It also works in the dry limbs. The adults are about half an inch in length and of a rusty brownish color.

Cerambycids Boring In Unsound Wood.

There are a large number of round-headed borers which breed in dead wood which has started to decay or in rotting logs, stumps and even in the unsound portion of standing trees. They are on the whole beneficial since they hasten the disintegration of forest debris, but otherwise are of very little economic importance.

The **Ponderous Pine Borer** (*Ergates spiculatus* Lec.) (Fig. 35) while not injurious to living trees, is often found by rangers and woodsmen in the larval

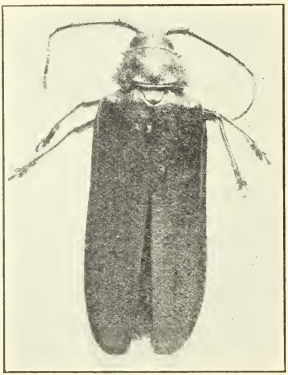

Fig. 35. The **ponderous pine borer** (*Ergates spiculatus* Lec.) is the largest forest beetle in California. Natural size. (Original.)

stage feeding in old pine or fir stumps. The grub is certain to attract attention on account of its large size, often measuring from two to three inches in length and half an inch in thickness. The adults are large brown beetles, often called "pinch beetles," and are found flying to lights during summer nights, or are found resting on or under the bark of old dead pines. They are the largest timber beetles found in California. Roots, stumps, logs, and standing trees of western yellow pine, Jeffrey pine, and Monterey pine which have been dead for more than a year are the preferred breeding places, although other dead coniferous trees probably furnish breeding grounds.

The **Harris Pine Borer** (*Tragosoma depsarium* (L.)) (*T. harrisi* Lec.) (*T. spiculum* Csy.) is a shiny, brown beetle about one and a quarter inches in length, the larvæ of which feeds in the dead wood of stumps and logs of western yellow pine, lodgepole pine and probably other pines in California.

The **Lion Beetle** (*Ulochætes leoninus* Lec.) during the larval stage bores in the dead roots and stumps of western yellow pine, sugar pine and probably also in Jeffrey pine and lodgepole, as well as in fir and hemlock. The adult beetles are about an inch in length, and resemble a bumblebee, since the wing covers are very short and do not hide the abdomen and wings.

Species of the genus *Leptura* and various related sub-genera commonly breed in old dead wood. Many of these are to be found in the pines. *Centrodera nevadica* Lec. has been taken by Van Dyke breeding in western yellow pine in Trinity County. *Ortholeptura valida* (Lec.) (*Leptura*) has been bred from Jeffrey pine, Monterey pine, and lodgepole pine. *Ortholeptura insignis* (Fall) (*Leptura*) has been found breeding in Monterey pine and Bishop pine. *Brachyleptura dehiscens* (Lec.) (*Leptura*) was taken by Garnett from small limbs of yellow pine at Calistoga. *Brachyleptura latifica* (Lec.) (*Leptura*) has been found breeding in Monterey pine, western yellow pine and digger pine. *Strangalia propinqua* (Bland) (*Leptura*) has been taken by Herbert from rotting wood of western white pine and lodgepole pine at Lake Tahoe. *Strangalia soror* (Lec.) (*Leptura*) was found by Garnett breeding in dead branches of western yellow pine. *Strangalia plagifera* (Lec.) (*Leptura*) has been bred by the author from the heartwood of old dead yellow pines. *Leptura brevicornis* Lec. has been bred from old wood of western yellow pine and lodgepole pine.

THE WEEVILS.

(*Curculionidæ.*)

The weevils are a group of beetles with the head prolonged into a snout or beak, which they use to puncture the plant tissue and make a hole for the reception of the egg. The larvæ are small, white, legless grubs with curved cylindrical bodies and usually do their feeding in decaying woody plant tissue, but at times are very destructive to living trees. Many of them are of considerable economic importance.

The Bark Weevils.

(*Pissodes*[1].)

The bark weevils of the Genus *Pissodes* represent a group of insects which attack the branches, twigs, and terminal shoots of many conifers. They often deform the trees by killing the terminal shoots and render them worthless as mature trees. Some species attack the base of young trees and by boring under the bark bring about their death. Other species simply breed under the bark of logs and in stumps of trees recently felled, or under the bark of dying standing trees.

Eggs are deposited in the crevices of the bark by the female beetle. On hatching the larvæ mine under the bark and form winding galleries which often score the sapwood. On reaching maturity they form a pupal cell, partly in the sapwood and partly in the bark, which is lined with excelsior-like shavings. The stout, fat, curved grubs, the character of their work and the very unique pupal cell readily distinguish these beetles from other species which may be found in the trees. Four species are found in California pines but only one or two are at all common.

The **Yosemite Pine Weevil** (*Pissodes yosemite* Hopk.) (Fig. 36) is the most common species which attacks western yellow pine, sugar pine, and western white pine. It commonly breeds in dying or dead trees, felled trees and stumps, but frequently attacks the base of young saplings just above the ground and by mining under the bark causes their death. The adults are reddish brown beetles 5–7 mm. in length.

The **California Pine Weevil** (*Pissodes californicus* Hopk.) is another species very similar to the above and is ordinarily not differentiated from it. It attacks western yellow pine in the high Sierras.

[1] Hopkins, A. D. "The Genus *Pissodes*." U. S. Dept. Agr., Bur. Ent., Tech. Series, No. 20, Part 1, 1911.

The **Terminal Pine Weevil** (*Pissodes terminalis* Hopping[1]), according to Hopping, attacks and kills the terminal limbs and stems of lodgepole pine in the Sierras from Kern to Lassen counties. It is often very destructive.

The **Monterey Pine Weevil** (*Pissodes radiatæ* Hopk.) is a common enemy of Monterey pine, but also attacks Bishop pine, knobcone pine, and probably other pines within its range. It is found infesting the thick bark at the base of saplings; in felled trees and stumps; or in the stems and tops of young trees. The adult is a light brown beetle from 6–7 mm. in length.

FIG. 36. The **Yosemite Pine Weevil** (*Pissodes yosemite* Hopk.) works under the bark of suppressed saplings and forms a cell lined with shredded wood fibre in which to change to the adult form. (Insert) Adult beetles. All natural size. (Photo by J. E. Patterson.)

THE TWIG WEEVILS.

Certain species of the genus *Magdalis* are also pine twig borers during the larval period. The adults feed on the needles of the pines and deposit eggs in the twigs. The grubs upon hatching burrow beneath the bark and cause the death of small twigs. There are ten species described from California, but most of them are rarely found even by the forest entomologist.

[1] Hopping, Ralph. "A New Species of the Genus *Pissodes*." Can. Ent., Vol. LII, Nos. 6 and 7, p. 132, June and July, 1920.

Magdalis lecontei Horn. (Fig. 37) is the species most commonly found feeding on the needles of young shoots of western yellow pine, Jeffrey pine and sugar pine. The adults are small beetles about 6 mm. in length and vary in color from a metallic green through blue to almost black. *Magdalis gentilis* Lec. is another bluish black species about 4 mm. in length which is said to feed on the needles of Jeffrey pine and probably other pines in the Sierra region. *Magdalis cuneiformis* Horn. is a dark blue species with black prothorax which also is said to attack the needles of western yellow pine and probably other pines in the Sierra region. *Magdalis proxima* Fall is a black species about 4 mm. in length which is reported as attacking Monterey pine and probably other pines through the Coast range and north into Oregon.

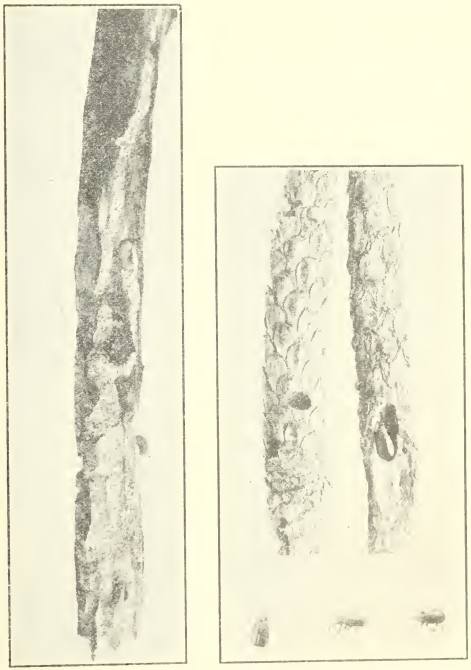

FIG. 37. Western yellow pine twigs injured by the twig weevil (*Magdalis lecontei* Horn.). Speckled white and brown boring dust and unlined pupal cells are characteristic of the work of these weevils. All natural size. (Original.)

Several species of the genus *Scythropus* are occasionally found in the adult stage feeding on the leaves of pines. They bite chunks out of the needles and leave a saw-tooth edge. *S. elegans* (Couper) is a metallic greenish bronze species about 5–7 mm. long. *S. albidus* Fall is ashy gray with a greenish tint and is often found on western yellow pine foliage. *S. californicus* Horn. is mottled black with reddish legs, and has been found on western yellow pine, Monterey pine and digger pine. *S. ferrugineus* Casey is metallic reddish brown or copper colored, and is often found on the foliage of western yellow pine, Jeffrey pine, knobcone pine and

The **Black-Bellied Clerid** (*Thanasimus nigriventris* Lec.) is a brown and gray beetle about 6 mm. in length, and is the most active enemy of the western pine beetle.

In the family *Ostomidæ* the **Green Trogositid** (*Temnochila virescens* Fabr. var. *chlorida* (Mann.)) (Fig 9e) is commonly found both in the adult and larval stage feeding upon various bark-beetles and wood-borers. The adults are a brilliant green or blue and from 10–13 mm. in length. They are general feeders and do not confine their attentions to any one species.

Corticotomus californicus V. D. is a small species which feeds on insects in dead limbs of western yellow pine. *Nemozoma attenuatum* V. D. is a shiny black beetle with a blue lustre which is predaceous on insects in dead Monterey pines.

A few species in the family *Colydiidæ* have been found to be predaceous on various bark-beetles, although they normally feed on decaying vegetable matter. *Aulonium longum* Lec. is a small, flat red beetle, 6 mm. in length, which is very commonly found in the burrows of the *Dendroctonus* and *Ips* beetles. It has been found occasionally both in the adult and larval state, feeding on the pupæ and adults of the western pine beetle. *Deretaphrus oregonensis* Horn. is a slender dull black beetle with corrugated wing covers, from 9–14 mm. in length, which has been found to be predaceous on the larvæ and pupæ of the flat-headed and round-headed borers. *Lasconotus pertenuis* Csy. has been found in the sapwood of Torrey pines, probably feeding upon small secondary insects. *Lasconotus subcostulatus* Kraus is commonly found in the galleries of bark-beetles in western yellow pine. *Lasconotus complex* Lec. is found associated with bark-beetles in lodgepole pine.

A very flat red beetle about 17 mm. in length is often found under the bark of western yellow pines which have been killed and abandoned by the bark-beetles. This is the **Red Cucujid** (*Cucujus clavipes* (Fabr.) var. *puniceus* (Mann.)), which is predaceous both in the adult and larval stage upon secondary bark-borers and termites.

The Lady Bird Beetles (*Coccinellidæ*) constitute a large family of beetles which are predaceous both in the larval and adult stages upon various scales and aphis. Several species are found feeding upon the scale insects infesting the pines.

THE MOTHS AND BUTTERFLIES.

(*Lepidoptera.*)

The moths and butterfles, although entirely harmless in the adult form, are often the parents of caterpillars which do tremendous damage to the forest. Occasionally an outbreak of caterpillars descends upon the forest and devours all of the needles from certain species of forest trees. Sometimes this results in the death of all or nearly all of the trees over large areas. Fortunately, no defoliator of such destructiveness has yet appeared in the California pine forests. Such defoliations as have occurred have stopped the growth of the trees until the needles could be replaced, but seldom have caused the death of any large number of trees. Minute caterpillars bore through the needles of certain pines and so weaken the trees as to make them easy prey to bark-beetles. Other species of caterpillars bore through the bark of trunks, limbs, tops or twigs, or bore through the cones, causing considerable local injury. At times they are a very injurious group of forest insects.

The sporadic outbreaks of leaf eating caterpillars and slugs usually come unheralded, the damage is caused during a single season, and the insects disappear before anything can be done about it. In other

cases defoliators may persist for several years or occur in alternate years over a period of time and can be combated to a certain extent by sprays or silvicultural methods.

All of this class of insects are leaf chewers and actually feed upon the needle growth. For this reason they can best be controlled by stomach poisons such as arsenate of lead. The most generally used spray formula for this purpose is composed of 25 lbs. powdered arsenate of lead and one gallon of fish oil (or linseed oil) in 400 gal-

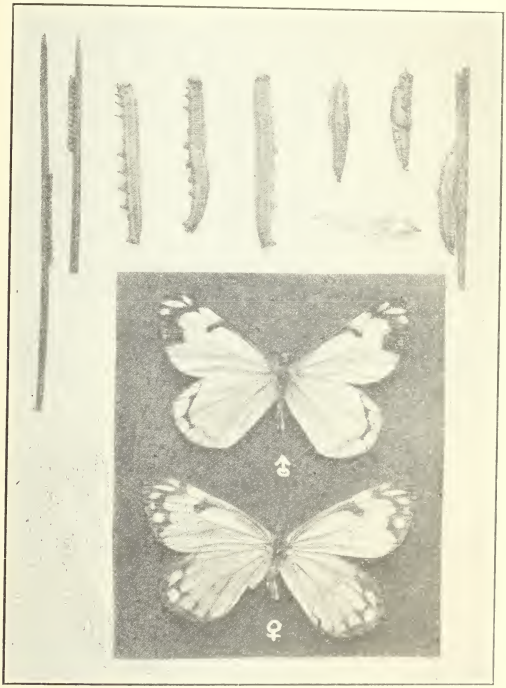

FIG. 39. Eggs, caterpillars, pupae and adults of the pine butterfly (*Neophasia menapia* Feld.). All nearly natural size. (After Evenden.)

lons of water. This spray was recently used along the highways in Yellowstone Park to protect the lodgepole pines from the ravages of two very destructive defoliating insects which were killing all of the lodgepole pine over a wide area.

Another method which has been suggested at times for the control of certain defoliators is the "light burning" of the forest. In the case of the Pandora moth, the larvæ and pupæ can undoubtedly be

destroyed in this way, but it is more than likely that the remedy would be worse than the disease.

BUTTERFLIES.

(*Rhopalocera.*)

Only one species of butterfly is of importance as a destructive pine feeder.

The **Pine Butterfly** (*Neophasia menapia* Felder[1]) is a very common defoliator throughout the northwest, at intervals completely defoliating large areas of pine timber and causing considerable injury to the health of the trees. In California, although often found through the northern part of the state, it has never been reported as doing any serious damage. Western white pine, sugar pine, western yellow pine and lodgepole pine seem to be the preferred hosts, although the caterpillars do feed on many other coniferous trees.

The adults are white butterflies with a few black markings on the wings and resemble the common cabbage butterfly. They fly during the late summer and fall and lay their eggs on the pine needles in the tops of the trees. The winter is passed in the egg stage. When the buds open in the spring, the caterpillars hatch from the eggs and feed upon the young needles, reaching full growth by the latter part of July. The full grown caterpillars are about an inch in length with pale green heads and with bodies of a dark green color with a slight purplish tinge, and with two yellowish white stripes along the sides. Upon reaching maturity, they drop to the ground by means of long silken threads and pupate on weeds or shrubs, and the adult butterflies emerge and fly before winter. Thus just one year elapses between the egg laying periods. No control appears to be feasible.

MOTHS.

(*Heterocera.*)

The moths, as represented by several families, include a number of species which are very injurious to certain parts of California pines.

The family *Saturniidæ* or Giant Silk Moths include a number of very large moths the caterpillars of which feed upon various plants besides deciduous and coniferous forest trees.

The **Pandora Moth** (*Coloradia pandora* Blake) (Fig. 40)—Periodically the caterpillars of this moth completely defoliate the western yellow pine and Jeffrey pine over large areas. All of the needles are eaten with the exception of the terminal buds. The result is a serious checking of the tree's growth, and a lowering of its vitality so that it becomes an easy prey for the bark-beetles. Since the terminal buds are not eaten the trees usually recover from the defoliation unless attacked by other insects.

With from 50 to 90 per cent of the foliage stripped from the trees, the forest takes on a grayish sickly appearance. During the feeding period large greenish spiny caterpillars will be found singly or in groups feeding upon the needles. These caterpillars reach a length of from two and one-half to three inches when full grown.

[1] Evenden, J. C. "The Pine Butterfly, *Neophasia menapia* Felder." Jour. Agr. Res., Vol. 33, No. 4, p. 339, Aug. 15, 1926.

FIG. 40. The Pandora moth (*Coloradia pandora* Blake.). (a) Young caterpillars feeding on the needles of western yellow pine. (b) Adult moth, male. Natural size. (Photo by J. E. Patterson.)

The adults are very large gray-brown moths with a wing expanse of from three to four inches and heavy cylindrical bodies an inch or more in length. During an infestation flight year thousands of these moths will be seen flying through the woods and fluttering up the trunks of the pines.

The flight occurs during July and August of alternate years. Eggs are laid in clusters on the trunk and limbs of the pines. The caterpillars, upon hatching, proceed to the needles and feed upon them until winter, when they go into hibernation in nests at the end of the needle clusters. Feeding is resumed the following year and continues until July, when they complete their growth; then they crawl or drop to the ground and burrow into it for a few inches, where they pupate and change to the chrysalis stage.

The Pai-Ute Indians of the Mono Lake region encircle the infested trees with a trench in which the caterpillars are caught when they descend from the trees. The caterpillars are then collected by the Indians, dried and ground into a paste which is called Pe-aggie and is used as a food. The pupæ are egg shaped, over an inch in length and of a dark red color; they are called "Bull Quanch" by the Klamath Indians, who dig them out of the ground and relish them as food. During years of bountiful harvest, the young Indians often become ill from a too hearty indulgence in the rich diet. Fortunately for the Indians and for the pine trees as well, the heavy epidemics only occur at intervals of about thirty years. The pupæ remain in the ground for a full year and emerge as full grown moths just two years from the time the eggs were laid. Epidemic defoliations have only been reported from Mono County and further north in southern Oregon. Since the epidemics are very intermittent, no control appears to be practical.

The TIGER MOTHS of the family *Arctiidæ* are represented by the **Silver-spotted Halisidota,** *Halisidota argentata* Pack. (*Euschausia*), which in the adult form is a reddish brown tiger moth with white dots on the fore wings. The caterpillars are very woolly black with yellow markings, and are occasionally found feeding on the needles of various coniferous trees. Monterey pines in the vicinity of Pacific Grove are often heavily defoliated.

A few moths of the family *Geometridæ*, or measuring worms, at times feed on pine needles and cause considerable injury. The Monterey pine looper (*Nepytia nigrovenaria* Pack.) has been found by Dr. H. E. Burke destroying the new shoots of native pines at Monterey. The caterpillars are a light green color and web the needles together at the tips of the branches. The adults are mottled gray moths with a wing expanse of one and one-half inches and bodies one-half inch in length.

The SNOUT MOTHS of the family *Pyralidæ* include a number of species which in the caterpillar stage are bark or cone borers in various California pines. They usually bore into the fresh green twigs or cones and cause a copious flow of pitch.

Dioryctria abietella D. & S. is a gray moth about three-quarters of an inch in length, the caterpillars of which feed in the twigs and cones of knobcone pine, lodgepole pine, western white pine, sugar pine, and western yellow pine, besides in the cones of many firs. *Dioryctria xanthænobares* Dyar is a golden brown moth about three-quarters of an inch in length which in the caterpillar stage attacks the cones and twigs of western yellow pine and knobcone pine.

The **Zimmerman Pine Moth**[1] (*Pinipestis zimmermani* (Grote)) in the adult stage is a gray moth about half an inch in length. The larvæ are dirty white, yellowish or greenish caterpillars and are about three-quarters of an inch in length when full grown. They bore under the bark of tops and limbs, causing a light flow of pitch and the ultimate death of the affected part. In the northwest they are

[1] Brunner, J. "The Zimmerman Pine Moth." U. S. Dept. Agr. Bul. No. 295, 1915.

often injurious to the tops of western yellow pine, lodgepole pine and Douglas fir, producing spike tops and the death of many trees in second growth stands. While the Zimmerman pine moth has not been definitely recorded from California, a very closely related species (*Pinipestis* sp.) has been found by the author attacking the tops and limbs of Coulter pine in the southern part of the state.

The larvæ of *Dasypyga alternosquamella* Rag. are small whitish or faint pinkish caterpillars, 22 mm. long when full grown, which feed on western yellow pine mistletoe in company with *Gelechia natalis* Hein.

THE NEEDLE MINERS.

(*Gelechiidæ.*)

The needle miners are the caterpillars of very small moths. As their name indicates, their habit is to mine out the central tissues of the pine

FIG. 41. Needles of lodgepole pine showing mines, caterpillars and pupæ of the lodgepole pine needle miner (*Recurvaria milleri* Busck). Natural size. (After Patterson.)

needles, leaving only the outer shell or epidermis. The mined needles turn yellow or brown and the whole tree takes on a sickly dying appearance. While not fatal to the trees, this work retards their growth and appears to make them particularly susceptible to bark-beetle attack.

The **Lodgepole Pine Needle Miner** (*Recurvaria milleri* Busck[1]) (Fig. 41) is the caterpillar which intermittently defoliates the lodgepole pines in Yosemite National Park and is probably one of the causative factors in the widespread epidemics of the mountain pine beetle in that region. The pale orange or yellow caterpillars mine the needles causing them to turn brown and to fall. This gives the forest the appearance of having been scorched by fire or attacked by a mighty

[1] Patterson, J. E. "Life History of *Recurvaria milleri*, the Lodgepole Pine-needle Miner, in the Yosemite National Park, California." Jour. Agr. Res., Vol. XXI, No. 3, May 2, 1921.

invasion of bark-beetles. Often the damage is mistaken for bark-beetle work, but an examination of the trunks of the trees is sufficient to determine whether or not bark-beetles are present, since the needle-miners cause no discoloration of the inner bark or cambium.

The needle miners require two years for the completion of their life cycle. Flight and egg laying occurs in alternate years during July and August. The caterpillars enter the new needles and feed or hibernate in them until the following August, when they abandon them and migrate to the new crop of needles in which they feed and hibernate until the next summer. Pupation occurs during June and July and the new moths, which are about half an inch in length and grayish white with black specks on the wings, emerge just two years from the time the eggs were laid. No control appears to be practical.

Other species of needle miners (*Recurvaria* sp.) have been found attacking the needles of western yellow pine, Jeffrey pine, and sugar pine, but seldom causing any serious injury.

Gelechia periculella Busck is a very small brown moth with a wing expanse of 22 mm. The small rose colored larvæ are found feeding in decaying cones of western yellow pine. *Gelechia natalis* Hein. is a small bluish gray moth with a wing expanse of 17 to 20 mm. The dirty white or pinkish larvæ, 15 mm. in length, are found feeding on western yellow pine mistletoe.

THE PITCH MOTHS.

(*Aegeriidæ.*)

These are a group of clear-winged, wasp-like moths, which lay their eggs on the surface of the bark, usually on the edges of wounds, and the young caterpillars mine in the bark and wood, causing an enlargement of the scars and a copious flow of pitch to form over the wounds. For this reason they are often called "pitch moths" or "pitch worms". They often cause serious damage to the tops of mature trees and small trees in plantations.

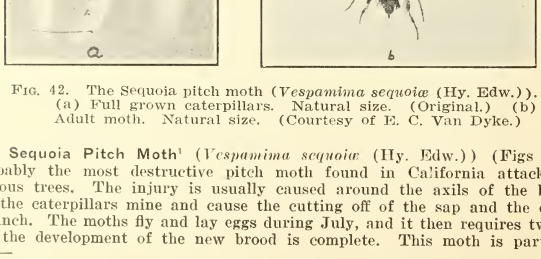

FIG. 42. The Sequoia pitch moth (*Vespamima sequoiæ* (Hy. Edw.)). (a) Full grown caterpillars. Natural size. (Original.) (b) Adult moth. Natural size. (Courtesy of E. C. Van Dyke.)

The **Sequoia Pitch Moth**[1] (*Vespamima sequoiæ* (Hy. Edw.)) (Figs 9d, 42) is probably the most destructive pitch moth found in California attacking the coniferous trees. The injury is usually caused around the axils of the branches where the caterpillars mine and cause the cutting off of the sap and the death of the branch. The moths fly and lay eggs during July, and it then requires two years before the development of the new brood is complete. This moth is particularly

[1] Brunner, Joseph. "The Sequoia Pitch Moth, a Menace to Pine in Western Montana." U. S. Dept. Agr. Bul. No. 111, 1914.

destructive to redwood, western yellow pine, sugar pine, Monterey pine, lodgepole pine and knobcone pine, and may also attack other pines within its range. The only known remedy is cutting the caterpillars out of the resin masses and destroying them, which of course is applicable only to valuable trees.

THE BUD AND TWIG MOTHS.

The Bud Moths.

The family *Tortricidæ* includes, besides the leaf rollers, a number of species of small moths the larvæ of which are very injurious to the terminal and lateral buds, needles, and cones of the pines.

Fig. 43. Pitch nodule formed on twig of lodgepole pine by the lodgepole pine twig moth (*Petrova metallica* (Busck)). Natural size. (Photo by J. E. Patterson.)

The **Sugar Pine Tortrix** (*Tortrix lambertianæ* Busck) is at times very destructive to the new buds and pollen bodies of sugar pine, killing as much as ninety per cent of the new growth on the trees. The caterpillars feed in colonies within a web on the terminal shoots and transform to adult moths during July. The adults are speckled tan to golden moths with a wing expanse of 22 mm.

The **Spruce Budworm** (*Cacœcia fumiferana* (Clem.)) (*Harmologa*) is a small brownish moth with a wing expanse of 19–22 mm. which at times in the caterpillar stage has been very destructive to firs, spruce, and hemlock in the northwest and has been found completely defoliating the fir trees over considerable areas in northern California. When epidemic a few of the larvæ feed on the western yellow pine or other pines in the vicinity but these are not the preferred hosts.

Species of *Rhyacionia* (*Evetria*) are bud moths, the larvæ feeding on the buds and new terminal shoots of pines. Their work is characterized by a resinous exudation at the point of attack but they do not form a pitch nodule on the stem. The **Monterey Pine Tip Moth** (*Rhyacionia pasadenana* (Kearf.)) is a silver gray moth about three-quarters inch in length with reddish marking which in the caterpillar stage bores through the buds of Monterey pine, causing a pitchy exudation and the deformation or death of the terminal growth.

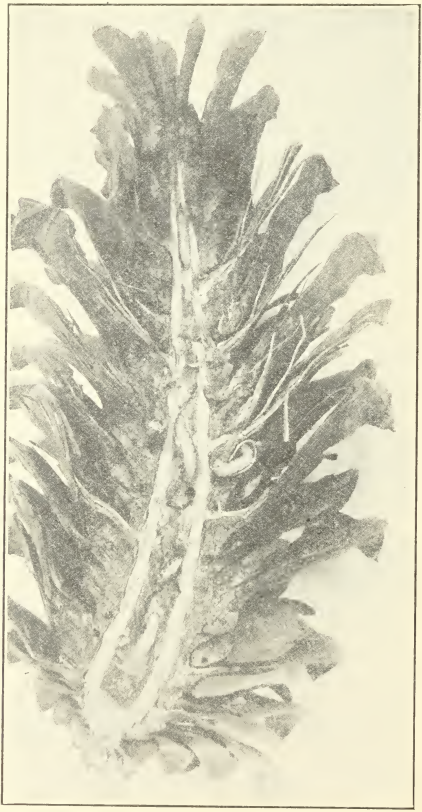

FIG. 44. Caterpillars of the yellow pine cone worm (*Laspeyresia piperana* (Kearf.)) feeding through the pith and seeds of a cone of western yellow pine. Natural size. (After Miller.)

The caterpillars of the genus *Petrova* (*Evetria*) bore into both the new and old growth of pine stems and branches and cause the formation of a nodule or round dirty lump of pitch and frass, which is typical of their work. They do not attack the buds. The larvæ feed and rest and finally pupate within the pitch nodule. The **Lodgepole Pine Twig Moth** (*P. metallica* (Busck)) (Fig. 43) attacks the small

branches and tips of stems of lodgepole pines of all sizes, in Yosemite Park. The purplish brown moths (16–19 mm.) fly and make their attacks during June and July. The species has a life cycle of two years. The **Digger Pine Twig Moth** (*P. sabiniana* (Kearf.)) is an orange yellow and white species with a wing expanse of about three-quarters of an inch, which in the larval stage feeds in the terminal twigs of digger pine, forming a pitch pocket in which the caterpillars live. The **Single-Leaf Pine Twig Moth** (*P. monophylliana* (Kearf.)) is a similar species found in the single leaf pine in Kern County.

Several species of the genus *Eucosma* are found in the larval stage boring through the scales and seeds of pine cones and into the terminal twigs. *E. sonomana* Kearf. in the larval stage bores through the pith of the terminal twigs of western yellow pine and Engelmann spruce. *E. bobana* Kearf. is an ochreous colored moth with white spots on the forewings and a wing expanse of 17-28 mm. The larvæ have been found boring through the cones and seeds of western yellow pine, Jeffrey pine and knobcone pine. *E. rescissoriana* Kearf. is a dark brick red moth with faint sprinklings of black scales (23 mm.). The larvæ feed through the cones and cone scales of lodgepole pine.

The Cone Moths.

These are the caterpillars of certain species of Tortricid moths which show a decided preference for pine cones.

The **Yellow Pine Cone Moth** (*Laspeyresia piperana* (Kearf.)) (*Laspeyresia miscitata* Hein.) (*Penthina toreuta* Grote) (*Cydia*) (*Carpocapsa*) (Fig. 44) in the caterpillar stage is a dirty white in color, about one-half inch long and has the habit of boring through the central pith of western yellow pine cones and then entering the seeds through their attachment to the central stem. They destroy great quantities of seed. The adults are small gray moths about half an inch in length.

The **Jeffrey Pine Cone Moth** (*Hedulia injectiva* Hein.), which is very similar to the above, is a very destructive enemy of Jeffrey pine cones and seeds. The adult moths are half an inch in length and nearly black.

SAWFLIES, HORNTAILS, PARASITES.

(*Hymenoptera.*)

The order *Hymenoptera* includes a large group of forest insects resembling wasps. The adults have four clear wings, and biting, sucking or lapping mouth parts. Most of the larvae, with the exception of the sawflies, are white bodied worms without prominent heads.

The sawflies, horntails, and a few of the chalcids are injurious to forest trees, but a large group including many chalcids and ichneumon wasps are beneficial in that they are parasitic upon the more harmful species. In fact nearly every injurious forest insect has one or more hymenopterous parasites which prey upon it and help to hold it in check. Only a few of the more common species can be mentioned in a paper of this length.

THE SAWFLIES.

(*Tenthridinidæ.*)

The false caterpillars or sawflies are so named because of the peculiar saw-like ovipositor with which the adults make incisions in the leaves to deposit their eggs. The larvæ or "slugs" are capable of quickly defoliating the trees and are often very destructive to pines, in some cases completely killing large areas of virgin forest. Several species are found in California but as yet only one has caused any geat amount of destruction.

The **Yellow Pine Sawfly** (*Diprion fulviceps* (Cress.)) (Fig. 45) in the adult stage is a black bodied fly about one-quarter of an inch long with prominent feathery

antennæ. The larvæ, which are green slugs with black heads, feed upon the foliage of western yellow pine. When full grown (about half an inch long) they make a cylindrical, brown, papery cocoon which is attached to the needles and in which they change to the adult form.

The **Sugar Pine Sawfly** (*Diprion edwardsii* (Nort.)) is a similar insect to the above except that the adults are yellow bodied instead of black. The slugs feed upon the foliage of sugar pine and western white pine in the Sierras. Several other undescribed species of *Diprion* attack the foliage of lodgepole pine, the firs and other conifers. *Strongylogaster pacificus* MacG. in the larval stage is a bluish green slug which constructs round, sawdust packed cells in the outer corky bark of western yellow pine, in which to pupate. The grubs probably feed upon the foliage of the pines.

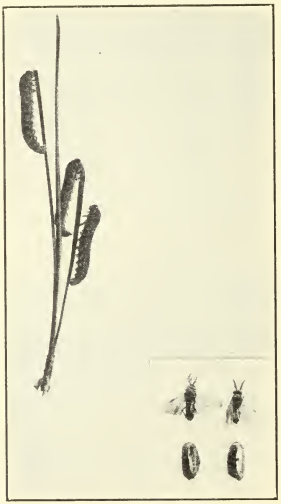

FIG. 45. Slugs of the yellow sawfly (*Dipron fulviceps* (Cress.)) feeding on pine needles. (Insert) Adult sawflies and the papery pupal cases from which they emerged. All natural size. (Original).

The **Monterey Pine Sawfly** (*Itycorsia* sp.) is a species which attacks only the Monterey pine in its native habitat near Pacific Grove. The "slugs" at times are very abundant and completely defoliate the trees, either killing large numbers of them or seriously stunting or weakening them. The larvæ are dark green or brownish slugs with black heads. Their work is characterized by the needles being sawed off or chewed into a mass of broken needles and brownish excrement pellets webbed together with silken threads. Where it is desired to protect park and shade trees, a poison spray such as arsenate of lead will probably be effective.

THE WOOD WASPS OR HORNTAILS.

(*Siricidæ.*)

The wood wasps or horntails are a group of large wasps which lay eggs in the solid wood of coniferous trees by means of a long slender

drill or "ovipositor." The worms hatching from these eggs bore winding holes through the sapwood and heartwood of the trees causing a great deal of damage to the timber. The galleries are tightly packed with fine sawdust and the worms are long cylindrical white grubs without legs or conspicuous heads. Upon reaching maturity these grubs transform into the wasp-like adults which bore perfectly round holes through the bark, emerge and fly to attack other trees. Water and fungi enter these exit holes and cause the rapid decay of the wood.

Many a woodsman on felling a fir tree has seen these "wasps" gather around and has marvelled at how it was possible for them to push such a delicate "stinger" down into the wood seemingly for an inch or more.

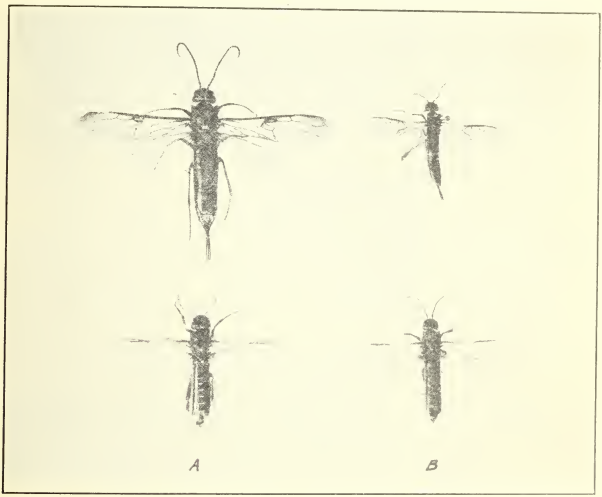

FIG. 46. Adult horntails which attack California pines. (A) *Sirex californicus* (Ash.)), female above, male below. (B) *Sirex behrensii* (Cress.)), female above, male below. Natural size. (Original.)

Often after the egg is laid the female becomes exhausted and is unable to remove the ovipositor and dies in this position on the tree.

No control appears to be practical.

There are seven species of horntails found in California, of which four species attack the pines.

Sirex californicus (Ash.) (Fig. 46a) is a large horntail wasp with dark metallic blue body, buff colored wings and black legs. It is known to attack western yellow pine, Jeffrey pine and lodgepole pine. The males are about one-half to three-quarters of an inch long and the females from one to one and one-quarter inches long including the ovipositor. *Sirex behrensii* (Cress.) (Fig. 46b) is a small wasp about five-eighths of an inch in length with the head and thorax blue black and the apical segments of the abdomen reddish brown. The ovipositor is very short. This species is commonly found attacking western yellow pine and sugar pine. *Sirex areolatus* (Cress.)—The female is of metallic steel blue color and the male blue with yellow transverse bands. It attacks redwood timber generally but also

breeds in lodgepole pine and Jeffrey pine and, according to Van Dyke, in Monterey pine.

Urocerus californicus (Nort.) is a very large ferocious looking wasp with a black body and amber wings. The females measure from one and one-quarter to two inches in length and have ovipositors which are long but not longer than the body. Males have yellow bodies and are much smaller. This wasp, while more commonly a fir feeder, has been found ovipositing in lodgepole pine.

Xeris caudatus (Cress.) is a very long slim wasp with an ovipositor as long or longer than the body. The abdomen is wholly black. The females measure about one and one-quarter inches in length. The favorite host of this species is lodgepole pine. *X. morrisoni* (Cress.) is found occasionally attacking lodgepole pine; it is similar to the above but with reddish abdomen.

The Seed Chalcids.

These are the larvæ of small wasps which drill their ovipositors through the young green cones and lay their eggs in the seeds. The worms upon hatching feed upon the growing tissue within the seed and completely destroy it. Most of them attack the seeds of firs and spruces.

The **Yellow Pine Seed Chalcid** (*Megastigmus albifrons* Walk.) **(Fig. 47)** attacks the seeds of western yellow pine.

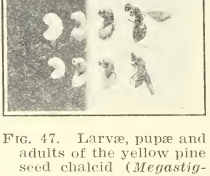

Fig. 47. Larvæ, pupæ and adults of the yellow pine seed chalcid (*Megastigmus albifrons* Walk.). Natural size. (Photo by J. E. Patterson.)

THE PARASITES.

Most of the parasitic enemies of the pine infesting insects are small wasps belonging to the families *Ichneumonidæ*, *Braconidæ* and *Chalcididæ*. Some of these do very effective work in holding certain insects in check, but among the forest insects very few are of much importance.

The adult wasps lay their eggs within the bodies of the larvae of the insect which they attack. The parasitic larva then hatches and lives within the body of its host gradually feeding upon it and finally destroying it before it reaches maturity. The following species are known to be parasitic on various pine infesting insects. There are a great many more as yet undescribed, and many whose habits have not been fully determined.

Of the parasitic wood-wasp family *Oryssidæ* one species, the western Oryssus (*Oryssus occidentalis* (Cress.)), is a shiny black wasp 8–14 mm. in length with reddish abdomen, which has been found by Burke to be parasitic on *Buprestis laeviventris* (Lec.) and *Chrysophana placida* (Lec.) in western yellow pines in California.

The family of **Braconids** (*Braconidæ*) are medium sized black or red shiny wasps with ovipositors of medium length. Many of these are important parasitic enemies of the pine wood-borers. *Apanteles californica* Muesebeck is a black wasp 2.8 mm. in length which has been found to be parasitic on the lodgepole pine needle miner (*Recurvaria milleri* Busck). *Apanteles laspeyresiæ* Vier. is a

black wasp 3.5 mm. in length with reddish appendages which is parasitic on the yellow pine cone worms *Laspeyresia* spp. *Phanerotoma erythrocephala* Roh. and *Phanerotoma laspeyresiæ* Roh. are small black wasps with reddish brown appendages and are also parasitic on the yellow pine cone worms (*Laspeyresia* spp.). *Lissonota dioryctriæ* Roh., *Microtypus dioryctria* Roh. and *Meteorus indigator* Riley are parasitic on *Dioryctria xanthænobares* in the cones of knobcone pine.

The family of **Ichneumons** (*Ichneumonidæ*) are mostly large sized black or red shiny wasps with long ovipositors. *Angita milleri* Roh. is a black wasp 4.5 mm. in length which is parasitic on the immature stages of *Dioryctria abietella* D. & S. in sugar pine cones. *Meloborus laspeyresiæ* Roh. is a black wasp 7.5 mm. in length with yellow, white and red markings on heads and legs, which is parasitic on the yellow pine cone worms (*Laspeyresia* spp.). *Pyracmon conocola* Roh. is black with red legs and 7.5 mm. in length and is parasitic on *Dioryctria xanthænobares* Dyar and *Pinipestes* sp. *Xorides californicus* (Cress.) is parasitic on *Buprestis læviventris* (Lec.) *Xorides catomus* (Davis) is black with reddish marking, 22 mm. in length, and is parasitic on *Chalcophora angulicollis* (Lec.). *Paemenia americana* (Cress.) (*Callicliisis*) is black with white and yellow markings and from 8–12 mm. in length and is parasitic on *Paratimia conicola* Fisher in the cones of knobcone pine and *Laspeyresia* spp., in Jeffrey pine and yellow pine cones. *Megarhyssa nortoni* (Cress.) is black with red and yellow markings and 25–38 mm. in length and is parasitic on *Xeris morrisoni* (Cress.) and other species of *Siricidæ*. *Ephialtes comstockii* Cress. is a black wasp with reddish markings and 10 mm. in length and is parasitic on the yellow pine cone worms (*Laspeyresia* spp.) in the cones of western yellow pine and Jeffrey pine; and on *Dioryctria xanthænobares* Dyar in cones of knobcone pine. *Odontaulacus edulis* (Cress.) has been found to be parasitic on *Paratimia conicola* Fisher in the cones of knobcone pine and upon *Buprestis aurulenta* L.

The family **Chalcididæ** includes many very small wasps which are parasitic on a number of pine infesting insects. *Hyssopus thymus* Gir. is parasitic on *Dioryctria xanthænobares* in cones of knobcone pine. *Zacalochlora milleri* Cwfd. is a small parasite of *Laspeyresia* spp., in cones of Jeffrey pine. *Cecidostiba burkei* Cwfd. is parasitic on *Dendroctonus brevicomis* Lec. in western yellow pine. *Cocophagus albicoxa* Howard is parasitic on the scale *Physokermes insignicola* Cwfd. in Monterey pine.

THE ANTS.

(*Formicidæ.*)

The large black and red **Wood Ants** (*Formica hæmorrhoidalis* Emery), which construct large nests on the surface of the ground built out of small twigs, are very active predators of the western bark-beetles during the time the beetles are emerging from the trees. They run over the bark and as soon as a beetle emerges they capture it before it can escape and carry it off to the nest. They are one of the important natural control agencies.

The **Carpenter Ants** of the genus *Camponotus* are large black ants which construct their nests in stumps, logs, or dead standing trees, often making large cavities in the dry wood. *Camponotus herculeanus* (L.) var. *modoc* Wheeler is the large shiny black species commonly found in the forests of the Sierras.

APHIS, SCALES AND BUGS.

(*Homoptera and Hemiptera.*)

A few of the scales, aphis and bugs attack the California pines and at times do some damage. These insects are equipped with beaks which they insert into the plant tissue and suck the juices. The only methods of control are through the use of contact sprays, such as lime-sulphur or oil emulsion sprays, but such methods are not adapted to forest con-

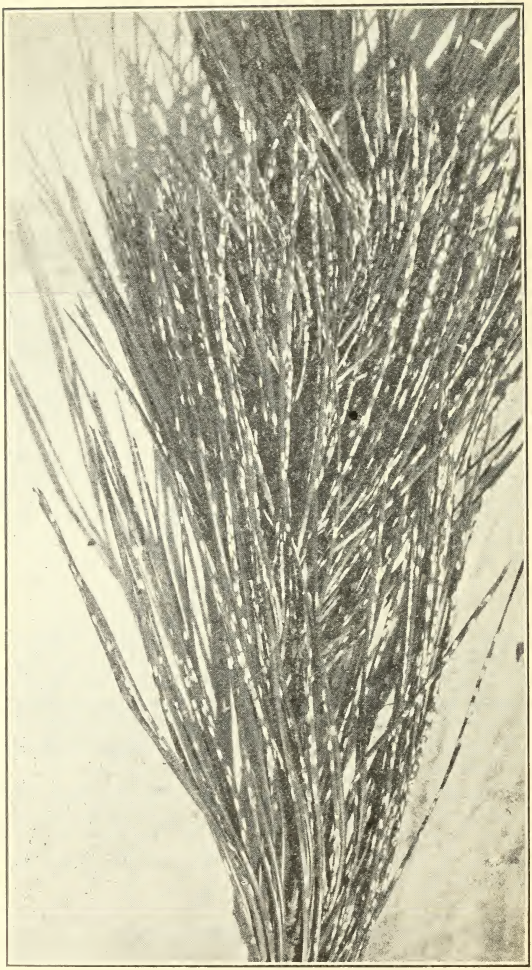

FIG. 48. Needles of western yellow pine covered with the pine leaf scale (*Chionaspis pinifoliae* (Fitch)). Nearly natural size. (Original.)

ditions and can only be used in the control of these pests on particularly valuable trees.

APHIS OR PLANT LICE.

(*Aphididæ.*)

These are small soft-bodied insects with pear-shaped bodies and with a pair of honey tubes at the posterior end of the body. They do not as a rule attack the pines, although they are commonly found on a great many other trees and plants.

The **Monterey Pine Aphis** (*Essigella californica* (Essig)) is a small light green bug about 1.5 mm. in length and with long hind legs which it uses to clasp the needles. Essig reports it attacking the Monterey pine and western yellow pine throughout the state.

Aphis of the genus *Dilachnus* are larger brown plant lice with long legs and with their bodies covered with powdery wax. They feed on the bark of various coniferous trees. *Dilachnus ponderosa* (Wms.) has been found feeding on the bark of terminal twigs of Jeffrey pine. *Dilachnus sabinianus* (Swain.) attacks digger pine twigs.

Schizolachnus pini-radiatæ (Davidson) is a dark green aphis covered with cottony wax and is found attacking the needles of Monterey pine and other pines in the bay region.

Chermes pinicorticis Fitch attacks the branches and twigs of Monterey pine and at times causes considerable injury. Its presence is indicated by small tuffs of white cottony material covering the affected limbs.

THE SCALE INSECTS.

(*Coccidæ.*)

Scales at times are quite injurious to young pines. These small insects suck the juices from the needles, or twigs, causing them to sicken or die, thus weakening the trees and either killing them outright or rendering them an easy prey to more destructive species of insects.

The **California Pine Scale** (*Aspidiotus pini* Comst.) (*A. californicus* Cole) is an elongate circular scale about one-sixteenth of an inch in diameter and of a yellowish brown to black color. It attacks the needles of western yellow pine, digger pine, knobcone pine, Monterey pine, and probably other pines, causing a serious weakening of the trees and occasionally their ultimate death. The young hatch during early spring and summer and settle upon the new needles of the host. From one to three broods are produced during the year and the winter is passed in a half grown condition.

Aspidiotus hederæ (Vall.) is reported by Essig as attacking Monterey pine. This is a very common scale and is a general feeder.

The **Pine Leaf Scale** (*Chionaspis pinifoliæ* (Fitch)) (Fig. 48) attacks the needles of western yellow pine, sugar pine, digger pine, Monterey pine and Torrey pine; and through sucking the juices causes the foliage to turn yellow and die, thus weakening the tree and occasionally bringing about its death. It is a narrow, elongate, white scale about one-eighth of an inch in length. The scales pass the winter as eggs under the female scale. These hatch in early spring and become full grown by midsummer, when another brood is hatched and develops before winter. It is found throughout the state.

The **Three-leaf Pine Scale** (*Matsucoccus fasciculensis* Herbert) is an elongate, oval, flat, wrinkled brown scale about 3–3.5 mm. in length which is found within the sheath or at the base of the needles of western yellow pine and digger pine. *M. acalyptus* Herbert is a similar scale which attacks the needles of pinon pine. It has recently been reported as causing severe damage to the single-leaf pinon pine on the Santa Barbara National Forest.

The **Monterey Pine Scale** (*Physokermes insignicola* (Craw.)) is a large, globular, shiny, light brown to black scale 4–6 mm. in diameter which attacks the tips

of Monterey pine branches and clusters on the stems at the base of the needles. It secretes a great deal of honey dew which causes a black smut to collect on the needles and twigs, thus making the trees very dirty, unsightly and objectionable as sidewalk trees. It is a very common pest on the Monterey and other pines around the San Francisco Bay region.

The **Irregular Pine Scale** (*Toumeyella pinicola* Ferris) (Fig. 49) is a slightly smaller scale than the above, of a paler color and wrinkled when full grown instead of smooth. It is commonly associated with the Monterey Pine Scale, infesting the terminal twigs at the base of the needles.

The **Cypress Mealy Bug** (*Puto cupressi* (Cole.)) is a large mealy bug covered with white cottony wax, which commonly attacks cypress and redwood trees. It is

FIG. 49. The irregular pine scale (*Toumeyella pinicola* Ferris) congregate in great numbers near the tips of Monterey pine twigs. (Photo by J. E. Patterson.)

recorded by Essig as attacking Monterey pine in the central coast region of California.

The **Pine Bug** (*Dendrocoris pini* Mont.) is a pale yellow bug from 5–6 mm. in length which has been recorded by Essig as feeding on the single leaf pine in California.

THE FLIES.

(*Diptera.*)

The large order of two winged flies (*Diptera*) includes a few families and species which are of interest to the forester. Some of the flies, in the larval stage, produce swellings or galls on various parts of the tree, others are predaceous or parasitic on various destructive species.

THE GALL MIDGES.

(*Cecidomyiidæ.*)

The **Monterey Pine Midge** (*Thecodiplosis piniradiatæ* (Snow & Mills)[1]) (Fig. 50). Monterey pines through the bay region are often severely injured by the work of this gall midge which causes a swelling at the base of the needles, stunts the needles or causes them to turn

FIG. 50. Monterey pine needles stunted and swollen at the base by a small gall midge (*Thecodiplosis piniradiatæ* (S. & M.)). Natural size. (Original.)

yellow and fall from the trees, thus weakening the trees and making them susceptible to bark-beetle attack. The adults are tiny pink flies about the size of mosquitos. They fly from January to March and lay their eggs at the base of the young terminal needles. The small yellow or pink maggots upon hatching burrow into the needles, causing the basal swelling, and continue to feed until November or December

[1] Snow, W. A. and Mills, Helen. "The Destructive Diplosis of the Monterey Pine." Ent. News, Vol. XI, p. 489, June, 1900.

when pupation occurs in the ground at the base of the tree. Control consists of destroying the pupae by cleaning up the debris at the base of the trees and burning it during the winter before the adults emerge from the puparia. Besides Monterey pine, it also attacks Coulter pine, digger pine, Bishop pine and knobcone pine in the bay region.

The **Monterey Pine Resin Midge** (*Retinodiplosis resinicoloides* (Wms.)[1]) is another small gall midge which inhabits the resin exudations of Monterey pine, but apparently is not injurious to the trees.

FIG. 51. The Nevada Termite (*Termopsis nevadensis* (Hagen)). Soldiers and workers in decaying sapwood of western yellow pine. Natural size. (Original.)

Itonida hopkinsi Felt in the larval stage is a small pink worm found in the mines of the pine bark-beetles.

BENEFICIAL FLIES.

Medeterus aldrichii (Wheeler) in the larval stage is a small white maggot which is predaceous on the larvæ and pupæ of *Dendroctonus*

[1] "The Monterey Pine Resin Midge," Williams, Francis X. Ent. News, Vol. XX, p. 1, Jan. 1909.

monticolæ and probably other bark-beetles in western yellow pine and lodgepole pine.

THE TERMITES OR WHITE ANTS.

(*Isoptera*[1].)

The "white ants," as their name signifies, are white, soft bodied insects resembling fleshy ants. They work in colonies in old wood and mine out the interior, leaving only a papery shell. They do a great deal of damage to telephone poles, the wood foundation of buildings, bridge timbers and similar wood products. They are commonly found in the wood of dead pines which have been killed by bark-beetles and in the stumps and wood of other coniferous trees.

There are eight species of termites listed from California. *Termopsis angusticollis* Hagen is a large species 15 to 19 mm. long. Most commonly found in the coast region. It works in moist wood, eating out the tunnels longitudinally with the grain of the wood. The Nevada Termite *Termopsis nevadensis* (Hagen) (Fig. 51) is a smaller species than the above and the adults are darker brown. It is usually found in the Sierra region.

Kalotermes minor (Hagen) is a common species inhabiting the *dry* wood of dead trees, branches, telephone poles, etc. It excavates longitudinal oval chambers. It has recently caused severe damage to buildings in southern California. *Kalotermes hubbardi* Banks is an insect with habits similar to the above and has been recorded from San Jose.

Reticulitermes tibialis Banks and *R. hesperus* Banks inhabit the ground and extend their galleries into wood which comes in contact with it.

Amitermes arizonensis Banks and *A. californicus* Banks are largely earth inhabiting species.

THE MITES.

The **Pine Needle Mite** (*Eriophyes pini* Nalepa[2]) is a very minute yellow blister or gall mite which has recently been found causing considerable injury to the needles of Monterey pine in Golden Gate Park, San Francisco, and to Torrey pines at San Diego, California. It feeds within the basal sheath of the needle cluster and causes a premature shedding of the needles, thus weakening the trees and making them more susceptible to bark-beetle attacks. A 10 per cent miscible oil spray has given fairly satisfactory results, but removal of badly infested pines may at times be necessary.

[1] Banks, N., and Snyder, T. E. "Revision of the Nearctic Termites," Bul. 108, U. S. N. Museum, 1920. Snyder, T. E., "White Ants as Pests in the U. S. and Methods of Preventing their Damage," Farmer's Bul. 759, U. S. Dept. Agr., 1916. "Tests of Methods of Protecting Woods against Termites or White Ants," Bul. 1231, U. S. Dept. Agr., 1924.

[2] Walthers, Enc. "The Pine Needle Mite (*Eriophyes pini*), a New Enemy of the Pines." Jour. Econ. Ent., Vol. 18, No. 6, December, 1925.

REFERENCES.

For those who may wish to delve more deeply into the study of forest insects of California, the following list of general reference works is given:

"An Introduction to Entomology"—J. H. Comstock, 1924. Comstock Pub. Co.
A general manual for the study of insects.

"Insects of Western North America"—E. O. Essig, 1926. Macmillan.
A very excellent systematic account of all the insects of economic importance in western North America, including a discussion of many forest insects. Well illustrated.

"Injurious and Beneficial Insects of California"—E. O. Essig, 1915. Supplement to Monthly Bulletin, California State Commission of Horticulture, Vol. IV, No. 4.
Includes illustrations, descriptions, and notes on many forest insects of California.

"Bark-beetles of the Genus Dendroctonus"—A. D. Hopkins. U. S. Dept. Agr. Bur. Ent., Bul. No. 83, Part I, 1909.
Contains a very complete discussion of this important group of bark-beetles, with illustrations of the different species. Unfortunately now out of print and difficult to obtain.

"Canadian Bark-beetles"—J. M. Swaine, Part II, Bul. 14, Dom. Can. Dept. Agr., 1918.
An illustrated systematic account of the scolytid bark-beetles injurious to forest trees. Many of the California species are mentioned.

"Forest Entomology"—W. J. Chamberlin, 1924. Edward Bros. Pub., Ann Arbor, Mich.
An account of the injurious and beneficial insects which affect forest and shade trees. In mimeographed form without illustrations. Includes considerable detailed information on the forest insects of California and other western states.

"Manual of Tree and Shrub Insects"—E. P. Felt, 1924. Macmillan Co.
A popular treatise on the shade and forest tree insects of the United States, giving brief descriptions of many California pine pests. Illustrated.

APPENDIX.

FOREST INSECT CONTROL.

Act 3704—General Laws of California, 1923.

AN ACT DECLARING INSECT PESTS, INSECT INFESTATIONS AND PINE BEETLES TO BE A NUISANCE, AND PROVIDING FOR THE CONTROL, ERADICATION AND DESTRUCTION OF SAID INSECT PESTS.

(Approved May 2, 1923.)

The people of the State of California do enact as follows:

SECTION 1. Pine beetles and other insect pests and infestations harmful, detrimental and injurious to timber and forest growths and to timber infested thereby are hereby declared to be a public nuisance.

SEC. 2. Every owner of timber or timberlands shall control, destroy and eradicate such insect pests, or provide for the same to be done on lands owned by him or under his control, but in case of his failure or neglect so to do, such work may be performed as provided for in this act.

SEC. 3. When any owner or owners of timber or timberlands shall find the same infested with pine beetles or other insect pests, or shall find timberlands adjacent thereto so infested, he or they shall immediately notify the State Forester thereof, whereupon it shall be the duty of the State Forester at once to investigate such condition, and if in his opinion the infestation is of such a character as to be injurious to forest growths and a menace to timber or timbered lands, the State Forester, with the approval of the State Board of Forestry, shall declare a district or zone of infestation, and declare and fix the boundaries thereof so as to definitely describe and identify such district. Thereafter and upon written application of the owners of sixty per cent or more of the timber or timbered lands within said infestation district that the provisions of this act be enforced and that said nuisance be abated and that the said insect pests be eradicated and destroyed, the State Forester shall at once notify all owners of timber and timberlands within the said district to proceed under the provisions of this act without delay to destroy and eradicate the said pests as provided herein. The said notice shall be by publication in a newspaper of general circulation in the district affected, and by personal service, or by mail addressed to the last known place of address of such owner sealed, plainly addressed, with the requisite amount of postage stamps thereon and deposited in the United States post office. Such service may be made on an agent of the owner, or upon any person of legal age in possession or residing upon said land.

SEC. 4. If the owner or owners referred to in the last preceding section fail, refuse or neglect to comply with the requirements of said notice for a period of thirty days after the date thereof, it shall be the duty of the State Forester, or the person or persons authorized and directed by him, to go upon said lands using such assistance and help as he may deem necessary, and to cause such insect pests to be eradicated and destroyed in such manner as shall be approved by the State Board of Forestry.

SEC. 5. Upon the completion of said work so directed and authorized, the State Forester shall at once notify all owners of timber and timberlands within the said infestation district or zone is situated a verified statement of the expenses necessarily incurred in performing the work of eradicating said pests. Upon the filing of said statement the county clerk shall cause the same to be entered upon a lien docket prepared and kept for that purpose. Said expense account when so filed and docketed shall constitute a first lien upon the timberlands upon which such work was performed, second only to the lien for taxes. If said charges and expenses shall not be paid and fully discharged within ninety days from the docketing thereof, it shall be the duty of the district attorney of said county to bring suit or action in the name of the State Board of Forestry for the foreclosure of the said lien, and the lands and timber included in said lien shall be sold in the manner provided by law under execution, and enough of the proceeds to satisfy the lien and costs shall be paid into the state treasury and deposited to the credit of the State Board of

Forestry. The overplus if there be any shall be paid to the owner of the property, if he be known, and if not, into the court for his use when ascertained.

SEC. 6. Every owner and all owners who, upon receiving said notice as provided in this act, shall proceed and continue in good faith to eradicate and destroy said pests shall be exempt from the provisions hereof as to the lands upon which he or they are so proceeding.

SEC. 7. Whenever the State Board of Forestry shall determine that control work within the designated zone or district of infestation is no longer necessary, said board by resolution may dissolve said district or zone, and whenever the owners of sixty per cent or more of the lands within said district or zone of infestation shall petition said State Board of Forestry to dissolve said district or zone for the reason that control work is no longer necessary or feasible, then the said board shall by resolution dissolve the same.

SEC. 8. Every owner in any such zone or district who is a member of a cooperative association of timberlands now existing or which may hereafter be formed, and which actively engages in the destruction, control and eradication of the said insect pests and pine beetles, using methods approved by the State Board of Forestry, shall be exempt from provisions of this act.

SEC. 9. For the purposes of this act any land shall be considered timberland which has enough timber, standing or down, to constitute, in the judgment of the State Board of Forestry, an insect or pine beetle infestation breeding ground of a nature to constitute a menace, injurious and dangerous to timber or forest growth in the district or zone under consideration.

SEC. 10. The word "owner" as used in this act shall include individuals, partnerships, corporations and associations.

THE FIELD IDENTIFICATION OF INSECTS ATTACKING CALIFORNIA PINES.

The determination of whether or not injury to forest trees is being caused by insects is usually a simple matter, since the insects give very concrete evidence of their work. Bark-beetles and wood-boring insects leave their signatures on the trees in the form of winding galleries, worm holes, pitch exudation or boring dust. Leaf chewing insects leave the imprint of their mandibles on the leaves. Sap sucking insects, such as scales, usually leave their skeletons behind as evidence. In many cases the work of certain species is so characteristic of them that nothing more than their work needs to be seen to tell what insect is responsible for the injury.

If the injury is new some stage of the insect will usually be discovered. In this connection it is important for the forester to remember that most insects which he will encounter have four stages of development: the egg, the larva or grub, the pupa or resting stage, and the adult or full grown insect. And for most of our forest insects, all of these stages, with the possible exception of the egg, are large enough to be seen with the naked eye.

In the case of the bark-beetles, eggs are laid by the adult in various parts of the tree. From these the larvæ hatch and commence their feeding. All of the insect's growth occurs in this stage, and the size of the adult beetle will be determined to some extent by the moisture and food available for the larva. When the larva completes its growth it transforms to a pupa or resting stage which has somewhat the form of the adult insect but is immobile and very fragile. The pupa gradually undergoes a transformation and the adult insect, usually with strong wings, is the final stage. The adults of some species do a certain amount of feeding, but their main purpose in life is to mate and travel to other host trees, deposit eggs and continue the propagation of their kind.

Another fact which simplifies field identification is that the pine insects of California are, in general, specialists. They not only confine their attacks to the pines but often to only one or two species of pine. Moreover, the insects which attack old trees do not as a rule bother young trees. And insects which feed under the bark of the main trunk do not attack the cones, needles or twigs. Each insect not only has its favorite host tree but some portion of that host tree where it thrives the best. There are, of course, exceptions to this general statement, but for all practical purposes it is the rule of the forest. From the forester's or timber owner's standpoint, this simplifies the problem immensely. Without being an entomologist he can identify the more commonly injurious insects through the host tree attacked, their position on the host tree, and their type of work. And further, this simplifies the problem of control when only one species of forest tree needs be considered in dealing with any given forest insect.

However, if there is any doubt as to the insect involved, samples of the injured part and of the insects found should be sent to some competent entomologist for identification. The entomologists of the federal and state departments of entomology or those of universities of the state are always glad to identify such material or send the inquiry to someone who has made a particular study of the pest.

The following synopsis of the typical symptoms of insect injury to pine, together with the key to the work and the host list, will probably aid the forester or timber owner in determining the insect responsible for the trouble.

PRELIMINARY DIAGNOSIS OF PRIMARY INSECT INJURY IN PINES.

Symptoms	Probable Causes	Page
1. Foliage of entire tree fading, turning yellow or red.		
(a) Outside of bark shows pitch exudations or sawdust collecting in crevices. Under bark find insect tunnels between bark and wood—made by hard shelled, reddish brown to black beetles, not entering wood.	1-a—Bark-beetles (usually *Dendroctonus* or *Ips*)	29, 41
(b) Outside of bark shows no pitch or sawdust exudation. Under bark find insect tunnels made by elongate white grubs—sometimes entering wood.	1-b—Flat-head Borers (usually *Melanophila*)	58
(c) No pitch or sawdust in crevices of bark, nor insect mines under bark, but minute caterpillars mining the needles.	1-c—Needle miners (*Recurvaria*)	79
2. Foliage at top or on one side of tree fading, turning yellow or red.		
(a) Similar evidence to 1 (a) on portion of trunk or top.	2-a—Bark-beetles (usually *Ips*)	41
(b) Similar evidence to 1 (b) on portion of trunk or top.	2-b—Flat-head Borers (*Melanophila*)	58
(c) Very heavy exudation of pitch at top of tree, bark splitting.	2-c—Pine Moths (*Pinipestis*)	78
3. Foliage on isolated branches or twigs dying, fading, turning yellow or red.		
(a) Very small brown beetles mining the twigs.	3-a—Twig Beetles (*Pityophthorus*)	53
(b) Cylindrical white grubs working through stems.	3-b—Twig Weevils (*Pissodes*)	69
(c) Caterpillars forming masses of pitch on terminal shoots.	3-c—Twig Moths (*Eucosma*, etc.)	81
4. Foliage appearing sparse or sickly; or partially or wholly stripped from the trees. No insects working under bark.		
(a) Needles covered with small scales. Trees looking sickly, or covered with black smut.	4-a—Scale Insects (*Coccidæ*)	89
(b) Needles chewed by insects.	4-b—Defoliators	74
(c) Needles stunted or swollen at base.	4-c—Gall Insects	91

GUIDE TO FIELD IDENTIFICATION OF THE MORE DESTRUCTIVE INSECTS ATTACKING CALIFORNIA PINES.

Based Upon the Character of the Work.

HOST TREE INDEX OF PINE FEEDING INSECTS.[1]

[1] In this index the insects are grouped as primary or secondary in the part of the tree where they are usually found. It should be understood that this is not absolute and that the insects follow no hard and fast rules. Some of the secondaries are at times primary and vice versa; those working under the bark of the trunk may also at times enter the wood. Some of the bark borers may in the adult stage even feed on the needles. However, in the majority of cases this classification of their activities will apply.

†Known to kill trees.

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GENERAL INDEX.

(Exclusive of host tree references.)

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