U. S. DEPARTMENT OF AGRICULTURE,
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L. O. HOWARD, Entomologist and Chief of Bureau.

PRACTICAL INFORMATION ON THE SCOLYTID BEETLES OF NORTH AMERICAN FORESTS.

I. BARKBEETLES OF THE GENUS DENDROCTONUS.

BY

A. D. HOPKINS, PH. D.,
In Charge of Forest Insect Investigations.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., March 31, 1909.

SIR: I have the honor to transmit herewith manuscript of the first part of a proposed bulletin of this bureau, to be entitled "Practical Information on the Scolytid Beetles of North American Forests."

The present part is entitled "Barkbeetles of the Genus Dendroctonus," and deals with the more practical results of extensive investigations by Doctor Hopkins between 1891 and 1908, and of those conducted by him and under his immediate supervision by field and office assistants of this Bureau, Messrs. W. F. Fiske, H. E. Burke, and J. L. Webb. It relates to the most destructive enemies of the coniferous forests of North America, gives practical methods for their control, and serves as a supplement to Technical Series No. 17, Part I, the two publications together making a very complete technical and popular monograph of the genus Dendroctonus, the major part of which is based on original research. It is believed that these contributions will mark an important era in the history of forest entomology in America, and should be of special value to the systematic and economic entomologist and to students of forest entomology. This part should be of exceptional interest and value to practical foresters in the management of National and State forests, as well as to private owners of forests. The illustrations are mainly reproduced from Technical Series No. 17, Part I.

I recommend the publication of this manuscript as Bulletin No. 83, Part I, of the Bureau of Entomology.

Respectfully,

L. O. HOWARD,
Entomologist and Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

PREFACE TO BULLETIN.

During the writer's investigations of extensive insect depredations in the forests of West Virginia, from 1890 to 1902, he was forcibly impressed with the importance of the forest-insect problem in connection with any future efforts toward the successful management of the forests of this country, and was thus led to give special attention to the subject. It was soon realized that among the principal groups of insect enemies of forest trees the scolytid bark and wood boring beetles must occupy first rank, both in economic importance and systematic interest. Subsequent investigations in West Virginia, in connection with the work of the West Virginia Agricultural Experiment Station, and in all of the principal forest regions of the country, in connection with the work of the Bureau of Entomology, have served to confirm these first impressions.

In these investigations special efforts have been made to acquire information on the habits and seasonal history and other facts relating to the various species, and to collect an abundance of material for systematic study, all to form a basis for conclusions in regard to the principal enemies of American forests and practical methods for their control.

The results of these investigations will be published in the two series of bulletins issued by the Bureau of Entomology. Those relating to the purely technical or systematic side of the subject, and of more direct interest to the systematic and economic entomologist and the general student of entomology, will be published in the technical series, while those of special interest to the economic entomologist, the student of forest entomology, the technical and practical forester, the owner of private forests, the manufacturer of forest products, and the public generally will be included in the regular, economic series of bulletins. The bulletins of each series are to be issued in parts, each part relating to a special group or genus as the work thereon is completed, thus avoiding the otherwise necessary delay in publication. A full index will be published to accompany each completed bulletin of several hundred pages.

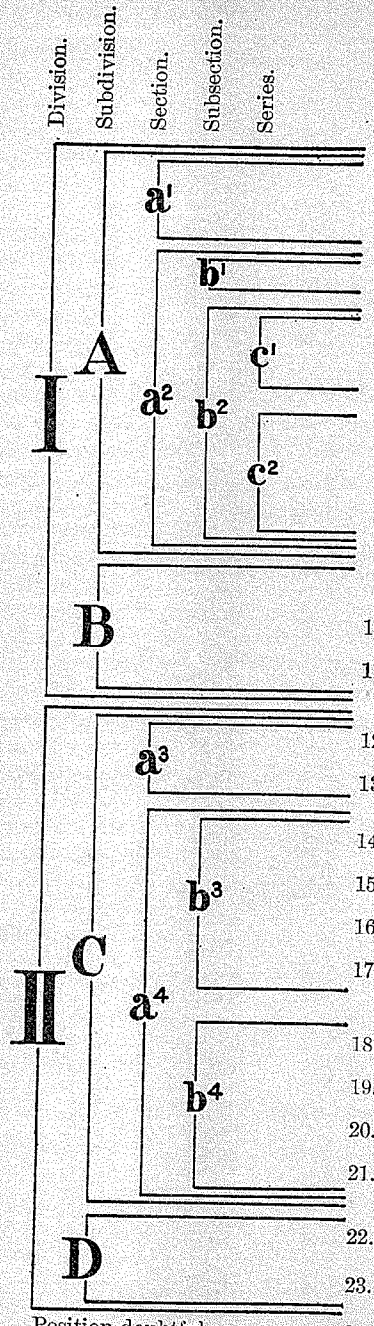
A. D. H.

CONTENTS.

ILLUSTRATIONS.

PLATES.

TEXT FIGURES.



Species number.	Technical name.	Common name.	Page.
1.	*brevicomis* Lec.	1. Western Pine Beetle.	42
2.	*barberi* Hopk.	2. Southwestern Pine Beetle.	49
3.	*convexifrons* Hopk.	3. Roundheaded Pine Beetle.	53
4.	*frontalis* Zimm.	4. Southern Pine Beetle.	56
5.	*arizonicus* Hopk.	5. Arizona Pine Beetle.	72
6.	*mexicanus* Hopk.	6. Smaller Mexican Pine Beetle.	74
7.	*parallelocollis* Chap.	7. Larger Mexican Pine Beetle.	74
8.	*approximatus* Dietz.	8. Colorado Pine Beetle.	76
9.	*monticolæ* Hopk.	9. Mountain Pine Beetle.	80
10.	*ponderosæ* Hopk.	10. Black Hills Beetle	90
11.	*jeffreyi* Hopk.	11. Jeffrey Pine Beetle	101
12.	*simplex* Lec.	12. Eastern Larch Beetle.	103
13.	*pseudotsugæ* Hopk.	13. Douglas Fir Beetle	106
14.	*piceaperda* Hopk.	14. Eastern Spruce Beetle.	114
15.	*engelmanni* Hopk.	15. Engelmann Spruce Beetle.	126
16.	*borealis* Hopk.	16. Alaska Spruce Beetle.	132
17.	*obesus* Mann.	17. Sitka Spruce Beetle	132
18.	*rufipennis* Kirby.	18. Redwinged Pine Beetle.	136
19.	*murrayanæ* Hopk.	19. Lodgepole Pine Beetle.	137
20.	*punctatus* Lec.	20. Allegheny Spruce Beetle.	139
21.	*micans* Kug.	21. European Spruce Beetle.	140
22.	*terebrans* Oliv.	22. Black Turpentine Beetle.	146
23.	*valens* Lec.	23. Red Turpentine Beetle.	153
24.	*adjunctus* Blandf.	24. Guatemala Beetle	

Classification of the Genus Dendroctonus, Showing Technical and Common Names and Species Numbers.

This diagram will enable the reader to refer at once to the technical and common names of any species number mentioned in the text, and will show at a glance the position and relations of the divisions, subdivisions, sections, subsections, series, and species into which the genus is divided.

PRACTICAL INFORMATION ON THE SCOLYTID BEETLES OF NORTH AMERICAN FORESTS.

I. BARKBEETLES OF THE GENUS DENDROCTONUS.

By A. D. Hopkins,
In Charge of Forest Insect Investigations.

INTRODUCTORY.

The first part of this bulletin supplements Technical Series No. 17, Part I, of this Bureau, in giving facts of practical interest and importance on a group of barkbeetles which contains the most destructive enemies of the principal coniferous forest trees of North America.

To avoid the too frequent repetition of technical and common names in the text or in footnotes, the species number is used, referring to the corresponding number in a classified list of technical and common names in Plate I.

The list of publications, in which references are to be found to some economic feature of one or more species, is arranged in chronologic instead of alphabetic order, so that the reference in the text is to the year in which the particular article referred to was published, as well as to the author's name. A more extensive bibliography is found in Technical Series No. 17, Part I.

HISTORICAL.

The name "Dendroctonus," which means *killers of trees*, was proposed in 1836 by Dr. W. F. Erichson to designate a genus of beetles which was then represented by two described species—the European spruce beetle (No. 21) (see Plate I) and the black turpentine beetle (No. 22). Between that time and 1897 ten more North American species, as at present recognized, were added, one (No. 18) by Kirby in 1837, one (No. 17) by Mannerheim, 1843, one (No. 23) by Le Conte, 1860, one (No. 4) by Zimmerman in 1868, two (Nos. 12 and 20) by Le Conte in 1868, one (No. 7) by Chapuis in 1869, one (No. 1) by Le Conte in 1876, one (No. 8) by Dietz, 1890, and one (No. 24) by Blandford in 1897. The writer has added twelve (Nos. 2, 3, 5, 6,

89535—Bull. 83, pt. 1—09——2

9, 10, 11, 13 to 16, and 19) North American species, but none has been added from any other part of the world. Therefore the genus is now represented by 23 species from North America and one from Europe.

The European species was early recognized as a destructive enemy of spruce and other coniferous trees, and much information has been published relating to its habits, life history, distribution, and methods of control.

Previous to the year 1891 only two species had been recognized in this country as depredators on forest trees. The black turpentine beetle had been referred to by Olivier, 1795, and the red turpentine beetle by Harris, 1826 to 1862, and by other writers, as enemies of pine, and the eastern spruce beetle (No. 14), under the name of another species (No 18), was recognized as a destructive enemy of the spruce in the northeastern United States and southeastern Canada and was the subject of special investigations and reports by several authors. In 1891 the writer found that the southern pine beetle (No. 4) was the cause of the death of pine and spruce timber over extensive areas in West Virginia and adjoining States, and it was the subject of special investigations and reports (Hopkins, 1892 to 1899). It was also mentioned in publications by Chittenden (1897), Schwarz (1898), and others.

In 1899 the writer made observations on the destructive habits of the western pine beetle (No. 1), the red turpentine beetle (No. 23), the mountain pine beetle (No. 9), and the Douglas fir beetle (No. 13), and observed the habits of the Sitka spruce beetle (No. 17). In 1900 the destructive work of the eastern spruce beetle (No. 14) in northwestern Maine was investigated, and in 1901 investigations were made on the Black Hills beetle (No. 10) and its depredations in the Black Hills of South Dakota were investigated.

Since July, 1902, many trips have been made by the writer to different sections of the country in general, and special investigations made of the work of one or more of the species of this genus, as noted further on, under "Basis of information," following the account of each species. Messrs. J. L. Webb, H. E. Burke, and W. F. Fiske, assistants in forest insect investigations, working according to the plans and under instructions of the writer, have given special attention to the study of the seasonal history, habits, etc., of the species found during their active field work.

Mr. Webb spent two seasons (1902 and 1906) in the Black Hills National Forest, principally in the study of the Black Hills beetle (No. 10) and its work and in conducting experiments with trap trees; one season (1904) in the San Francisco National Forest, giving special attention to species 2, 3, and 8, and one season (1905) in central Idaho, studying the western pine beetle (No. 1) and in conducting

experiments with trap trees. He also spent the season of 1906 in the Black Hills to complete the investigations on the Black Hills beetle and the season of 1907 in the national forests of southern New Mexico and Arizona in general field work.

Mr. Burke spent three seasons (1903, 1904, and 1905) in western and northwestern Washington in general forest insect investigations, and made observations on the Sitka spruce beetle (No. 17) and the Douglas fir beetle (No. 13). He also made special trips to Idaho and South Dakota in 1904 to determine certain facts relating to the western pine beetle (No. 1) in Idaho and the Black Hills beetle (No. 10) in South Dakota. In 1906 he spent the greater part of the season in the Yosemite National Park, under instructions to make special studies of the mountain pine beetle (No. 9), the western pine beetle (No. 1), and the red turpentine beetle (No. 23), and in 1907 he made observations on the southwestern pine beetle (No. 2), the Black Hills beetle (No. 10), and other species in the forests of Utah.

Mr. Fiske gave special attention to the investigation of the southern pine beetle (No. 4) and its work, experiments with trap trees, etc., during his general investigations of forest insects in the South Atlantic and Gulf States during the seasons of 1903, 1904, 1905, and 1906, and studied the seasonal history and habits of the black turpentine beetle (No. 22) and the red turpentine beetle (No. 23)—the latter in the mountains of North Carolina. In the fall of 1906 he made observations on the eastern larch beetle (No. 12) and the redwinged pine beetle (No. 18) in northwestern Michigan, and in the spring of 1907 he made observations on species 4 and 22 in Texas and on species 2, 3, 5, 8, 13, 15, and 23 in southern New Mexico.

This field work by the writer and his assistants has resulted in the accumulation of a mass of material in specimens and notes which has served as a basis for the preparation of this part of the bulletin.

Considerable material has also been received from officials of the Forest Service, together with information in regard to the location and extent of depredations, and from owners of private forests and other correspondents in different sections of the country who have notified us of troubles affecting the timber and have responded to our requests for specimens and detailed information in regard to the character and extent of the depredations.

DESTRUCTION CAUSED BY THE BEETLES.

The results of our investigations have clearly shown that some of the species of this genus of beetles are the most destructive enemies of the coniferous forest trees of North America. As examples, we have only to cite the well-known depredations by the eastern spruce beetle (No. 14) in the northeastern United States and New Bruns-

wick during the past century (Hopkins, 1901*a*), the widespread destruction of pine and spruce by the southern pine beetle (No. 4) in West Virginia and Virginia in 1891 and 1892 (Hopkins, 1899*a*), the destruction of a large percentage of the timber in an entire National Forest by the Black Hills beetle (No. 10) within the past ten years (Hopkins, 1902*b* and 1905), and the depredations by the western pine beetle (No. 1) in Idaho, Oregon, and California (Webb, 1906), and by the mountain pine beetle (No. 9) in Wyoming, Montana, Idaho, Oregon, Utah, and California noted in the present paper.

CHARACTER AND EXTENT OF DEPREDATIONS.

Living healthy trees are attacked by swarms of the adult beetles, which enter the bark on the main trunk and excavate their egg galleries for a distance of a foot or more through the inner, living bark. This weakens the vitality of the tree, and in addition the larvæ hatching from the eggs mine through and destroy the bark intervening between the egg galleries, thus completely girdling the trees and causing their death. The amount of timber killed in this manner during the past century has been enormous. That known to have been killed by these beetles in West Virginia, New England, and the Black Hills National Forest alone amounts to many billions of feet of the best pine and spruce, to say nothing of the less conspicuous depredations each year scattered through the forested sections of the Rocky Mountain, Cascade, Sierra, and Coast regions, and of the Southern States. Very conclusive evidence has also been found that some of the great denuded areas in the Rocky Mountains region supposed to have been caused by forest fires were primarily caused by one or more species of Dendroctonus. From our present knowledge of the facts and evidence it is probable that if the timber destroyed by these insects in the United States during the past fifty years were living to-day its stumpage value would be more than $1,000,000,000.

POSSIBILITIES OF CONTROL.

The results of our investigations, experiments, and practical demonstrations make it clear that wherever private forests or State or National forests are under organized management for fire protection and economic utilization the control of these insects is often a less difficult and less expensive problem than that of controlling forest fires. In fact, wherever there is a sufficient demand for the timber, and where facilities for the utilization of the trunks of the infested trees within a specified time exist, the desired control may often be brought about and maintained practically without cost or even at a profit, especially if the action be taken before the depredators have spread over extensive areas.

If, when first discovered, the depredations of the beetles have already involved an extensive area, or if they are neglected until a large percentage of the timber is killed, their artificial control will be as difficult and expensive as that of a neglected forest fire. Furthermore, if the depredations occur in an inaccessible section of the forest or where the conditions as to labor and other facilities are unfavorable for necessary action, nothing more can be done toward the control of the beetles than under the same conditions in controlling a fire. But with the rapid extension of modern forest management, lumbering operations, and working plans into the principal public and private forests, and especially with the adoption of fire-control regulations under an organization of fire patrols and rangers, there will be no excuse for neglecting the insects.

THE BEETLE PROBLEM AS IMPORTANT AS THE FIRE PROBLEM.

In certain sections of the country and in certain National Forests where the more destructive species of beetles are present and a constant menace to the standing timber, the beetle problem is undoubtedly as important as the forest-fire problem, and therefore demands the adoption and organization of beetle-control work, which, with little or no additional force and equipment, can be conducted by fire patrols and forest rangers.

The evidence of destructive beetle work is not quite as distinct as is the evidence of fire, and can not be seen quite so far, but a clump of yellow-top or red-top trees can be seen for a long distance, and upon closer inspection the pitch tubes and boring dust on and around the trunks of living trees are sufficient danger signals to demand that the required action be taken to prevent widespread depredations.

There is one great advantage in the requirements for successful beetle control over those for fire control, viz, there is usually a period of six to ten months in which to utilize or otherwise dispose of the affected timber to destroy the broods of beetles in the bark, while a fire requires immediate attention.

DISTINCTIVE CHARACTERS OF THE GENUS.[a]

The beetles of the genus Dendroctonus (see figs. 1, 2, 3, etc.) are distinguished in the adult stage by their cylindrical, somewhat elongate to stout bodies, broad and prominent heads, nearly round to oblong-oval and transversely placed eyes behind the base of each antenna, the last with an elongate, clublike basal joint (scape) followed by 5 short joints (funicle) and terminated by a broad club which is thickened at the base and flattened toward the apex, and

[a] See also Technical Series No. 17, Part I, for technical descriptions of genus, species, etc.

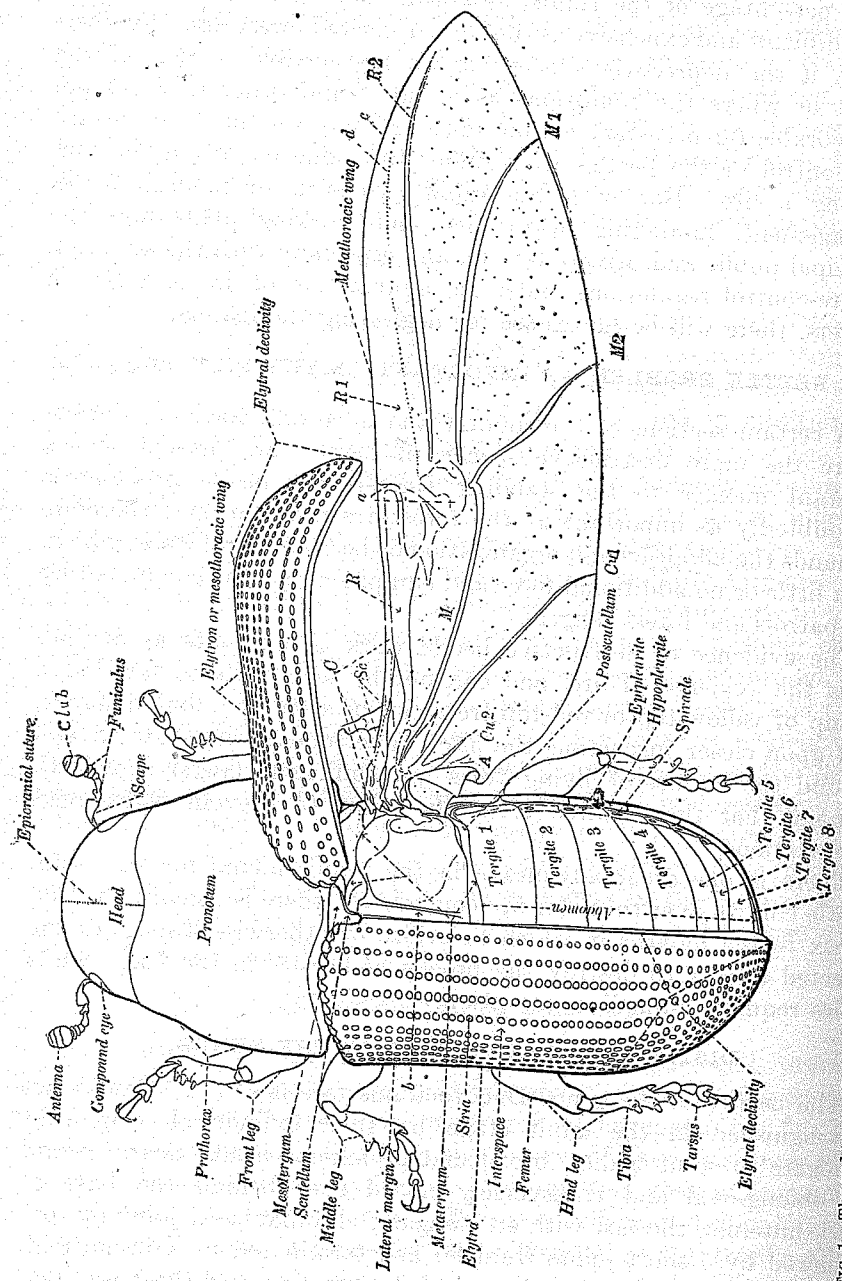


FIG. 1.—The red turpentine beetle (*Dendroctonus valens*). Adult, dorsal aspect, greatly enlarged; *a*, Median fold; *b*, scutellar groove; *c*, costal margin; *d*, inter-radial fold; *Sc*, subcosta; *R*, radius; *R1*, radius 1; *R2*, radius 2; *C*, costa; *M*, media; *M1*, media 1; *M2*, media 2; *Cu1*, cubitus 1; *Cu2*, cubitus 2; *A*, anal. (Author's illustration.)

has three to four closely connected joints defined by curved lines. The front of the head has a distinct middle elevation toward the base of the mandibles, called the epistomal process (see figs. 2, 3). The pronotum is slightly more than half to slightly less than half as long as the elytra, which have fine to coarse rugosities between rows of obscure to distinct punctures.

The diagram, Plate I, gives the technical and common names of the beetles of the genus, and shows how the different species fall into natural primary and minor divisions according to certain structural characters and peculiar habits.

ADULT CHARACTERS.

In the species of Division I the pronotum is somewhat elongate and as broad as the elytra, and in those of Division II the pronotum is shorter and is usually narrower than the elytra.

In species 1 to 8 (subdivision A) the body is somewhat slender, and the pronotum is but slightly narrowed toward the head, which in all but species 3 (comprising subsection b^1) has a frontal groove and two frontal elevations. In species 1 and 2 (section a^1) the elytra are without long hairs, while in species 3 to 8 (section a^2) there are long hairs toward and on the declivity.

In species 9 to 11 (subdivision B) the body is stouter and the pronotum is distinctly narrowed toward the head, which is without frontal groove or elevations. In species 9 and 10 the punctures of the pronotum are moderately coarse and deep, while in species 11 they are shallow and usually fine, with the surface more shining.

In species 12 to 21 (subdivision C) the punctures of the pronotum are of irregular size, while in species 22 and 23 (subdivision D) they are regular.

In species 12 and 13 (section a^3) the striæ of the elytral declivity are deeply impressed, and the interspaces are convex, while in species 14 to 21 (section a^4) the striæ are but slightly or not at all impressed and the interspaces are flat or but slightly convex. In species 14 to 19 the striæ of the elytral declivity have obscure to fine punctures, while in species 20 and 21 the strial punctures are coarse and distinct. Species 22 and 23 are easily distinguished by their large size, evenly punctured pronotum, which is subelongate and almost as broad as the elytra, and by the very large and prominent head.

EXTERNAL SEXUAL CHARACTERS.

In species 1 to 8 (subdivision A) the females are distinguished by a transverse, rather broad, elevated ridge across the pronotum near the anterior margin, moderately broad head, and moderately large mandibles. The males are without the transverse ridge across the

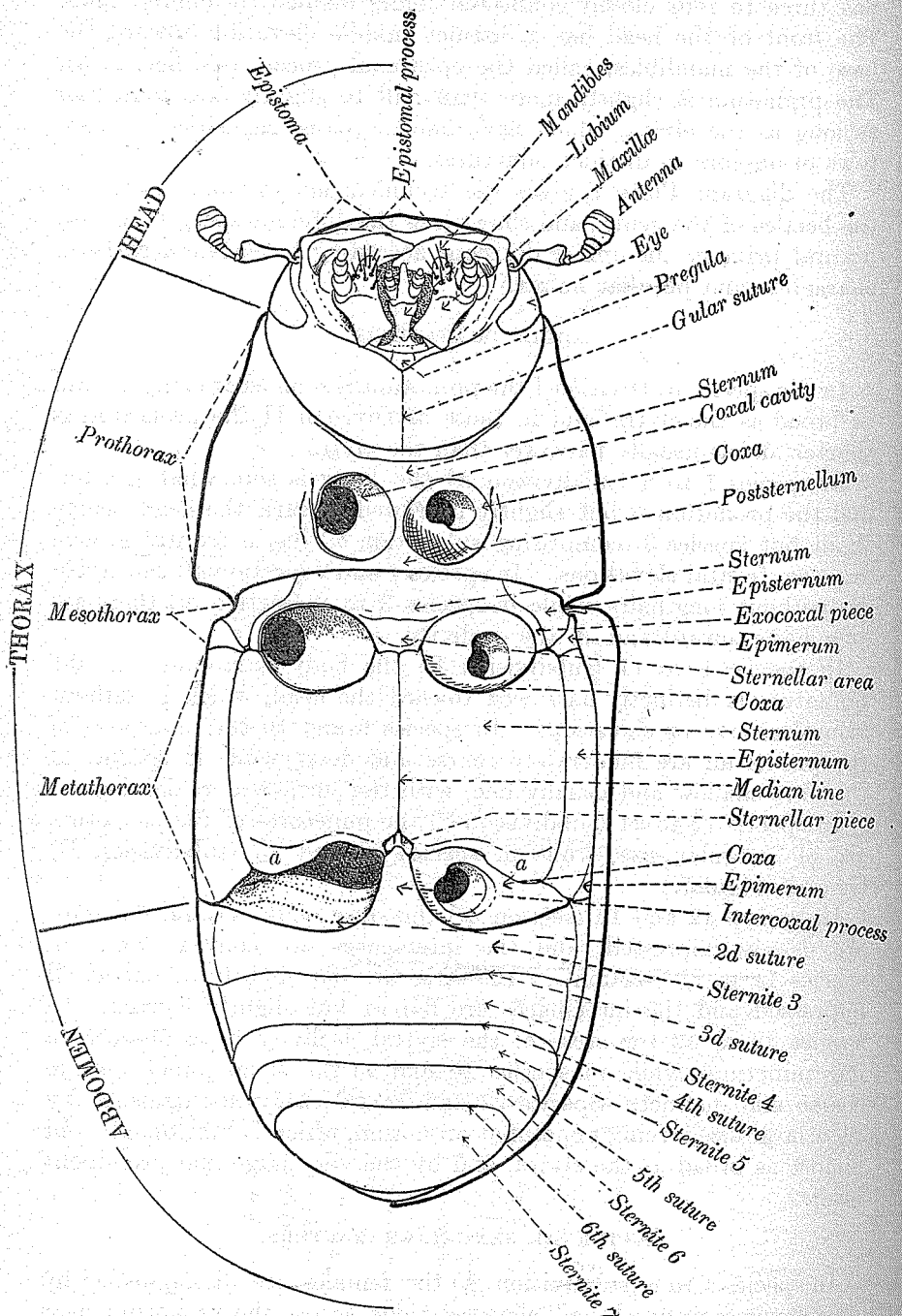


FIG. 2.—The red turpentine beetle. Adult, ventral aspect, greatly enlarged: *a*, Sternellar area. (Author's illustration.)

pronotum; but the frontal groove and tubercles are usually more distinct, the head broader, and the mandibles stouter.

In species 9 to 11 (subdivision B) the females have the declivity of the elytra somewhat flattened and shining and the interspaces with

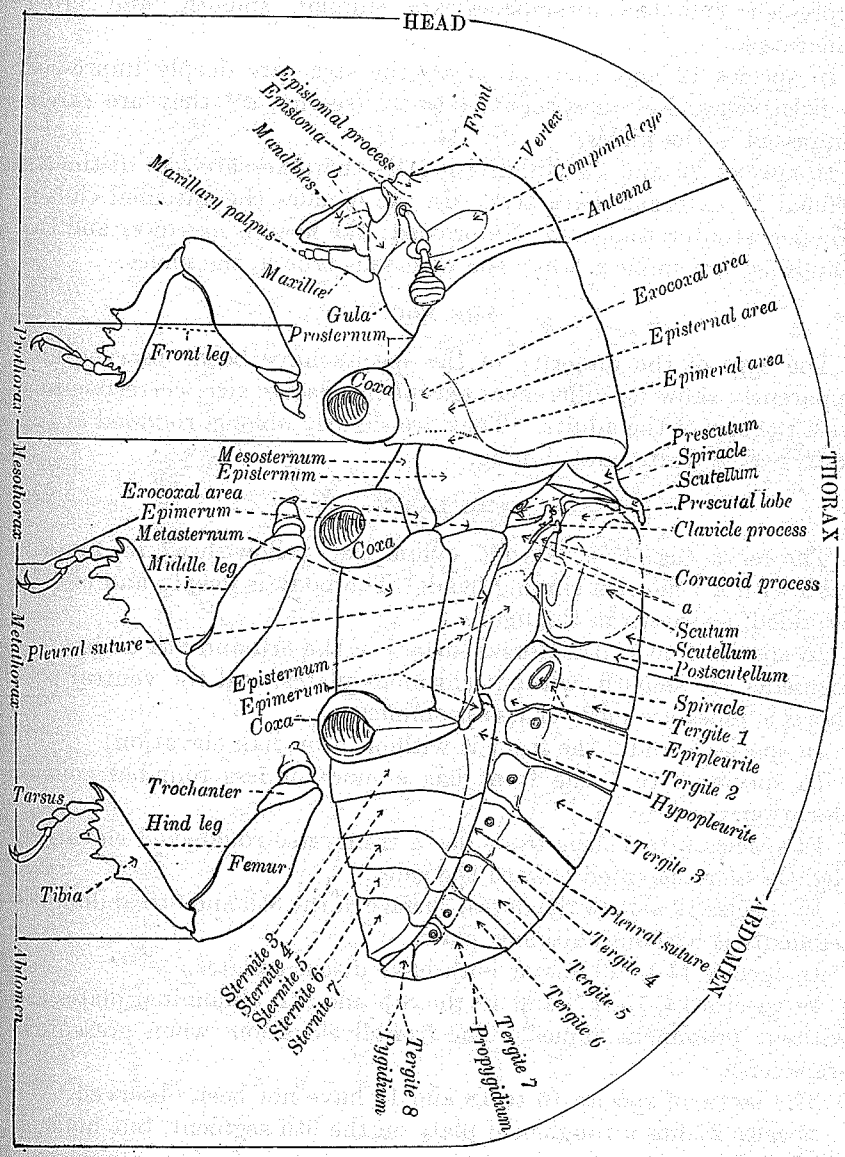


FIG. 3.—The red turpentine beetle. Adult, lateral aspect, greatly enlarged: *a*, Pleural clavicula; *b*, pregena. (Author's illustration.)

small granules and sometimes punctured. In the males the declivity is more convex, the interspaces have coarser granules, the head is broader, and the mandibles are stouter.

In species 12 to 21 (subdivision C) the sexes are easily distinguished by the differences in the declivity of the elytra. In the females the striæ are more distinctly impressed and the interspaces more convex and roughened. In the males the striæ are much less or not at all impressed and the interspaces are shining, smooth, and often punctured.

In species 12 and 13 (section a^3) the striæ are deeply impressed in both sexes; but in species 14 to 21 (section a^4) they are rarely impressed in the males.

In species 22 and 23 (subdivision D) the sexes are less distinctly defined by external characters. In the females the antennal club is broader, stouter, and more compressed; the head is narrower and the mandibles are smaller, while the reverse is true in the males.

THE EGG.

The eggs of the majority of the species have been observed and apparently show no differences except in relative size, corresponding with the size of the adults. They are slightly oblong, rounded at the ends, pearly white, and shining.

THE LARVA.

The larva (fig. 4) is a stout, cylindrical, yellowish-white, footless grub with a yellowish shining head. The body is deeply and closely wrinkled, as shown in the figure.

In species 1 to 11 the dorsal surface of the 8th and 9th abdominal segments are smooth, without chitinous plates, and the ventral prothoracic lobes are more or less prominent.

In species 1 and 2 the front is without a median elevation.

In species 3 to 7 the front has a more or less rounded convex elevation.

In species 9 to 11 the front has a transverse roughened elevation, slightly more elevated toward the sides.

In species 12 and 13 the dorsal surface of the 8th and 9th abdominal segments is without chitinous plates.

In species 14 to 23 one or both have distinct plates.

In species 14, 15, 17, and 19 the 8th and 9th abdominal plates are without prominent spines. The frontal elevation, when present, is transverse.

The larvæ of species 16 to 18 and 19 have not been observed.

Species 21 has a roughened plate on the 9th segment, but none on the 8th.

In species 12 the front is without a median elevation, but in species 13 there is a distinct transverse, rugose, median elevation, more elevated toward the sides.

In species 14, 15, and 19 the front has a transverse elevation, but in 17 it is absent or indistinct.

In species 22 and 23 the dorsal plates of the 8th and 9th segments have prominent spines, and the front of the head is without elevations.

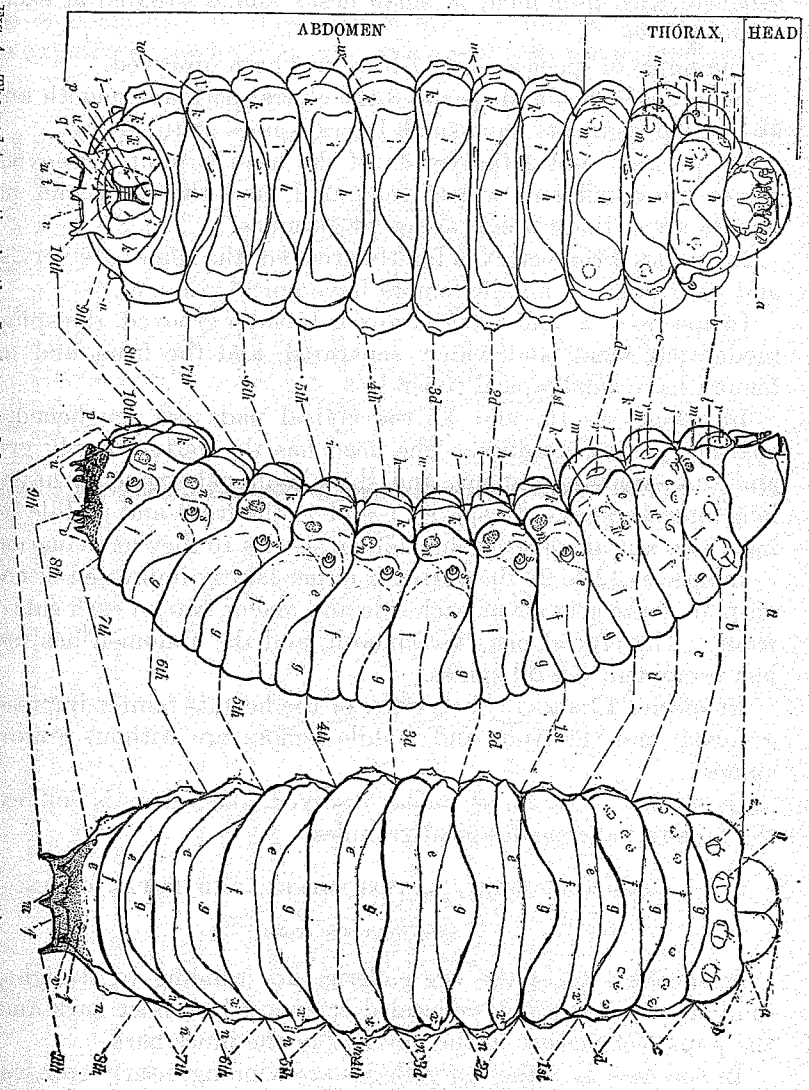


FIG. 4.—The red turpentine beetle. Larva, ventral, lateral, and dorsal aspects, greatly enlarged. *a*, Head; *b*, prothoracic segment; *c*, mesothoracic segment; *d*, metathoracic segment. Lobes: *e*, Scutal; *f*, scutellar; *g*, presectal; *h*, sternal; *i*, sternellar; *k*, poststernellar; *l*, hypopleural; *m*, epipleural. *m*, *m*, Foot calli; *n*, *n*, epipleural calli and tubercles; *o*, infrasanal lobe or callus of the 10th segment; *p*, perianal lobe or 10th pleurite; *q*, suprasanal lobe or tergite of the 10th segment; *r*, hypopleural tubercle; *s*, frontal prominence; *t*, process on 8th segment with scutellar spines; *u*, dorsal plate of 8th segment with scutellar spines; *v*, frontal tubercle; *w*, process on dorsal plate of 9th segment with scutellar spines; *x*, prothoracic lateral plate. (Author's drawing.)

THE PUPA.

The pupa (fig. 5) is of the general color of the larva, but is of the general form and size of the adult, with the legs and wing pads folded beneath the body and the abdominal segments exposed. The 9th segment has two prominent fleshy spines, and the other segments are

with or without dorsal, lateral, and pleural spines, which vary in size among the different species from very smooth to quite coarse and prominent.

In species 1 to 5 and 8 to 11 the vertex or front of the head is grooved, with prominent or small fleshy spines situated at each side of the groove.

The pupæ of species 6 and 7 have not been observed.

In species 1 to 5 and species 8 the elytral pads are smooth and the abdominal segments have small lateral spines or tubercles.

In species 1 and 2 the vertex of the head is faintly grooved, the spines are small and widely separated, and the front and middle femora are without apical spines or granules.

In species 3 the vertex is faintly grooved, the spines are very small, and the front and middle femora have apical granules.

In species 4, 5, and 8 the vertex is broadly grooved, the spines are moderately small and widely separated, and the front and middle femora have small apical tubercles.

In species 9, 10, and 11 the elytral pads are roughened, with sparsely placed granules. The head has the vertex deeply grooved and the spines prominent, and the abdominal segments have very long lateral spines. In species 9 and 11 the front and middle femora have two apical spines each, while in species 10 they have one each.

In species 12 to 23 the vertex is either faintly impressed or convex, with an acute granule at each side and one or two on each side on the front. The elytral pads are smooth, and the abdomen has more or less prominent lateral spines.

In species 12 and 13 the vertex of the head is faintly impressed or grooved, and the front and middle femora are without granules or spines.

In species 14 to 23, so far as observed, the vertex is convex, and the femora have small apical granules.

EGG GALLERIES, LARVAL MINES, AND PUPAL CELLS.

(See figures of work.)

In species 1 to 11 the egg galleries are winding to straight, with individual larval mines concealed or exposed in inner bark and with the pupal cells either in the outer or in the inner bark.

In species 1 to 8 the egg galleries are winding, nearly transverse to oblique; the larval mines short, not in groups; and the pupal cells are in the outer bark. In species 1, 2, 5, 6, 7, and 8 the larval mines are concealed, while in species 3 and 4 they are exposed in the inner bark.

In species 9 to 11 the egg galleries are longitudinal, slightly winding to straight. The larval mines are short and usually in groups.

and both the pupal cells and larval mines are exposed in the inner bark.

In species 12 to 23, so far as observed, the egg galleries are longitudinal, straight to slightly winding, with the larval mines either in groups or connected, or they form a broad common chamber, and all are exposed in the inner bark. The pupal cells are located at the

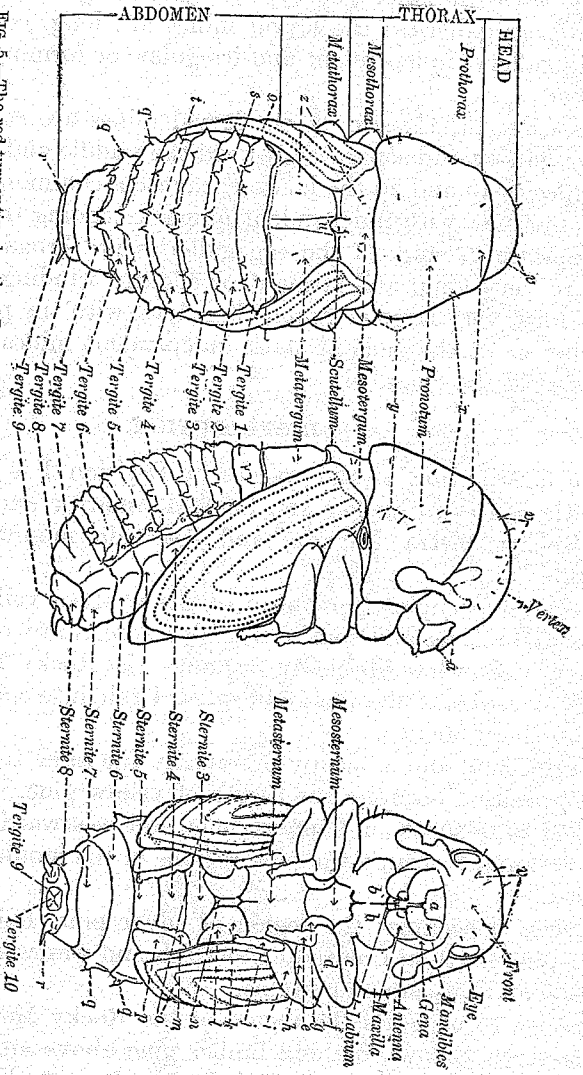


FIG. 5.—The red turpentine beetle. Pupa, dorsal, lateral, and ventral aspects, greatly enlarged: *a*, Epistomal bristle-pad or pseudo-labrum. Anterior leg: *b*, *b*, Coxæ; *c*, femur; *d*, tibia; *e*, tarsus; *f*, apical spines of femur. Middle leg: *g*, Coxa; *h*, femur; *i*, tibia; *j*, tarsus. Posterior leg: *k*, Coxa; *l*, femur; *m*, tarsus. *n*, Sternellar or intercoxal area; *o*, elytral pad; *p*, wing-pad; *q*, pleural spines; *r*, caudal spine or 9th pleural; *s*, lateral spines; *t*, dorsal spines; *u*, scutellar groove; *v*, frontal spines; *w*, dorsal spines of pronotum; *x*, lateral spines of pronotum; *y*, pleural spines of pronotum; *z*, mesotergal and metatergal spines. (Author's illustration.)

end of the larval mines or in the larval chambers and are usually exposed.

In species 12 to 13 the egg galleries are straight or slightly winding, sometimes branched, the larval mines are in groups and exposed in the inner bark, and the pupal cells are exposed or concealed.

In species 12 and 13 the egg galleries are long, longitudinal, straight, or slightly winding, sometimes branched, and moderately broad; the larval mines are long, independent of each other from the start, winding, and more or less regular.

In species 14 to 21, so far as observed, the egg galleries are broad, moderately long, straight, irregularly branched at terminals, and usually with an inner gallery through the packed borings of the finished egg galleries; the larval mines are long, connected toward the egg gallery, independent and irregular, or forming a broad larval chamber.

In species 14, 15, and 17 the larval mines are connected toward the egg gallery and separated toward the middle and outer ends.

In species 19 and 20 the larvæ excavate a common or social chamber, sometimes with independent mines extending from the edges.

In species 22 and 23 the egg galleries are broad to very broad, short to very long, and straight or slightly winding, and the larval mines form very large common chambers, with the pupal cells in the chamber or at the ends of short independent mines extending from the edge of the chamber.

DISTRIBUTION.

The distribution of the species of Division I is from the South Atlantic States to Mexico and Central America, and northward into the Rocky, Sierra Nevada, and Cascade mountains to British Columbia.

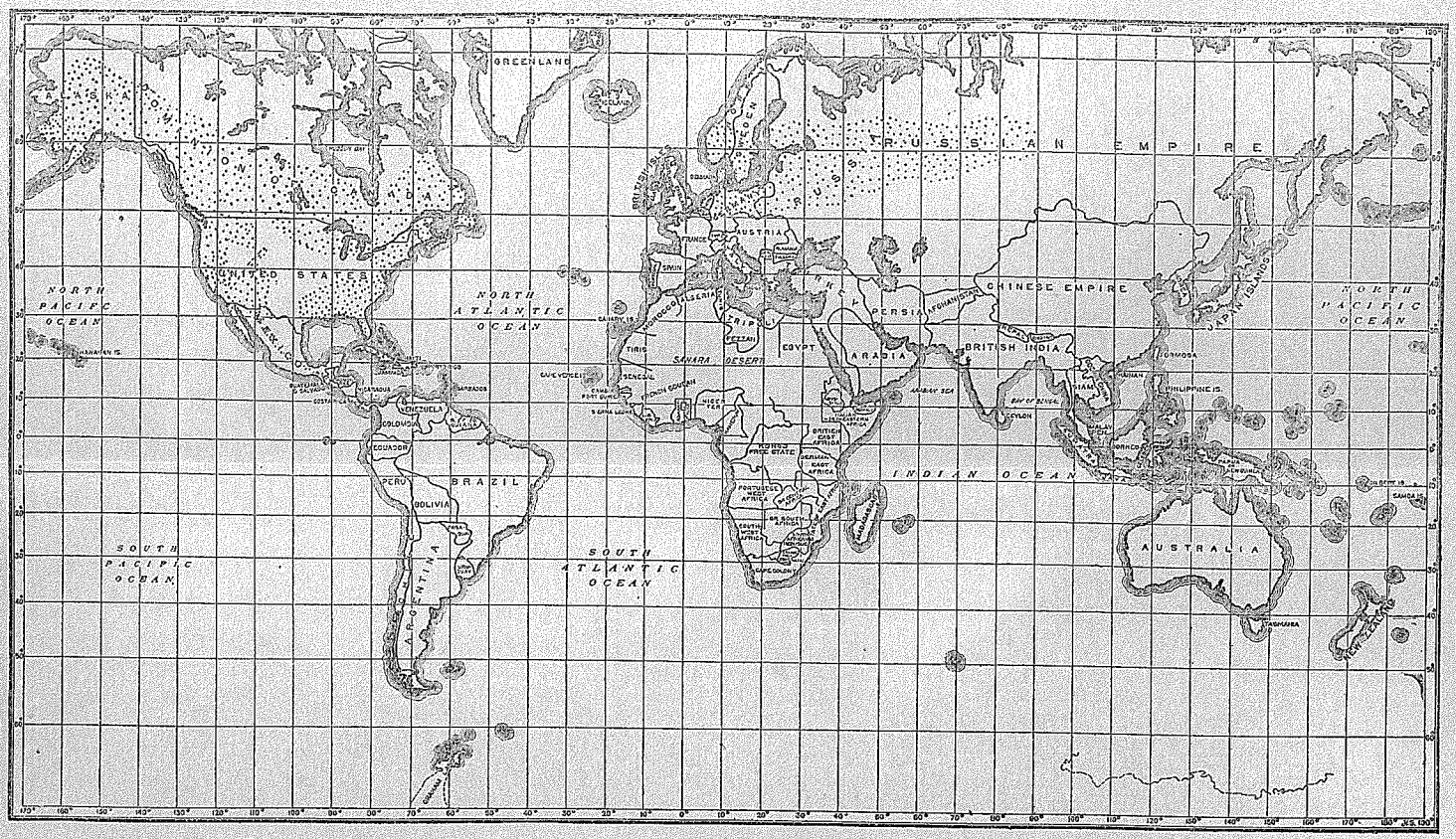
Species 1 occupies the region of the western yellow pine west of western Montana and southern Idaho, southward to Santa Barbara County, Cal., while species 2 occupies the Rocky Mountains region south of central Colorado and central Utah, into southern California and northern Mexico.

Species 3, 5, and 8 occupy practically the same region as species 2, while species 4 occupies the region of yellow pine, loblolly pine, and longleaf pine south of Pennsylvania and westward into Texas, and species 6 and 7 occupy the pine regions of the mountains of southern Mexico.

Species 9 occupies the region of silver pine, lodgepole pine, and sugar pine north of Colorado and Utah and westward into the Sierra Nevada and Cascade mountains.

Species 10 occupies the region of the Rocky Mountain variety of the western yellow pine and limber pine above an altitude of 6,000 feet, from western South Dakota southward through Wyoming, Colorado, and Utah to southern New Mexico and Arizona, while species 11 occupies the Jeffrey-pine region from the mountains of San Bernardino County, Cal., to northern California, and probably into Oregon.

Bul. 83, Part I, Bureau of Entomology, U. S. Dept. of Agriculture.



MAP OF THE WORLD, SHOWING DISTRIBUTION OF THE GENUS DENDROCTONUS. (AUTHOR'S ILLUSTRATION.)

The species of Division II range from Guatemala northward to Alaska, eastward to the Atlantic coast, and across northern Europe and Russia into Siberia.

Species 12 occupies the regions and sections of eastern larch from northwestern West Virginia, northward and westward, while species 13 occupies the region of the Douglas fir, bigcone fir, and western larch from southern New Mexico and Arizona to Ventura County, Cal., and northward into British Columbia.

Species 14 occupies the region of red spruce from the high mountains of Pennsylvania northward and from New Brunswick to northwestern Michigan, and probably northwestward to the 100th meridian.

Species 15 occupies the region of Engelmann spruce from the white spruce in western South Dakota westward, and north of southern New Mexico.

Species 16 occupies the white-spruce region in Alaska, and species 17 the Sitka-spruce region from southern Oregon to Sitka.

Species 18 occupies the Lake Superior region; species 19 the region of lodgepole pine from central Colorado northward probably into British Columbia; species 20 the regions of red spruce from the mountains of West Virginia into New York; while species 21 occupies the spruce and pine regions north of central Europe in Denmark and through Russia to eastern Siberia.

Species 22 occupies the region of pitch pine, Virginia pine, yellow pine, loblolly pine, and longleaf pine from Long Island, New York, east of the Allegheny Mountains, southward to Florida and Texas, and west of the mountains from the Little Kanawha River probably through Kentucky and Tennessee, while species 23 occupies the regions of pine timber from the Atlantic to the Pacific north of the South Atlantic and Gulf States and south into the mountains of Guatemala. Species 24 is described from Guatemala.

The distribution maps (figs. 11, 14, 17, etc.) show the known and probable ranges of each species, the known range being indicated by large dots and the probable range by small dots.

The distribution of the genus is shown on a map of the world (Pl. II.)

HOST TREES.

In Division I the species confine their attack to pine and spruce, but principally to the pines.

Species 1 confines its attack to the western yellow and sugar pine, and is a destructive enemy of both. Species 2 attacks the western yellow pine, but, so far as observed, is much less destructive than its northern and western neighbor. It has also been found in the Douglas fir, but this is evidently an abnormal habit.

Species 3, 5, and 8 are usually associated with No. 2 in the western yellow pine, but none of them has been especially destructive, although independently or collectively they are capable of being so. Species 4 attacks all of the pines and spruces within its range, and while it caused widespread devastation in its northern range during 1891 and 1892 its destruction of timber within its southern range, so far as observed, is comparatively moderate.

The species of subdivision B are the most destructive insect enemies of western pine forests. Species 9 attacks the western white pine, silver pine, sugar pine, lodgepole pine, and western yellow pine, and is exceedingly destructive in certain localities throughout its range, especially to the silver pine, sugar pine, and lodgepole pine. Species 10 attacks the Rocky Mountain variety of the western yellow pine, limber pine, white spruce, and Engelmann spruce, but confines itself principally to the yellow pine and is exceedingly destructive, as has been conclusively demonstrated in the Black Hills Forest Reserve of South Dakota and in numerous localities in Colorado. Species 11 attacks the Jeffrey pine and western yellow pine, but principally the former, to which it is quite destructive.

The species of Division II attack pines, spruces, larches, and Douglas fir, and some of the species are very destructive to living timber.

Species 12 confines its attack to the eastern larch. There is no positive evidence that it is primarily destructive to living timber, but it evidently contributes to the death of trees defoliated by the larch worm. Species 13 confines its attack principally to the Douglas fir, but is also found in the bigcone spruce and western larch. In the northwestern section of its range this species is not especially destructive, but in its eastern and southern range it is very destructive to the Douglas fir.

Species 14 attacks the red spruce, black spruce, and white spruce, and from time to time during the past century it has been exceedingly destructive to the red spruce in Maine and New Brunswick. Species 15 attacks the Engelmann and evidently the other spruces of the Rocky Mountain region. There is conclusive evidence that it has caused widespread devastation of matured spruce during the past fifty years, and it is now quite aggressive in some localities. Species 16 has been found in the white spruce, but nothing more is known of its habits. Species 17 attacks the Sitka spruce, but there are no records to indicate that it has been primarily destructive to living timber. Species 18 lives in the white pine, but nothing further is known of its habits. Species 19 attacks living lodgepole pine and Engelmann spruce, but it is not known whether or not it is primarily destructive. Species 20 was found in the living bark on a red-spruce stump in West Virginia, which is all that is known of its habits.

Species 21 is recorded as attacking spruce and pine principally, and as sometimes attacking larch, and fir (Abies), and is recognized as a destructive enemy.

Species 22 attacks the different species of pine within its range and has also been found in spruce. It is sometimes destructive to living trees, but more often is simply injurious to the base of the trunks in causing basal scars. Species 23 attacks all of the pines and is sometimes found in spruce and larch. It rarely causes the death of trees but causes serious damage to the base of living trees, resulting in the common defect known as basal scars and fire wounds.

EVIDENCES OF ATTACK.

In all of the species the first evidence of attack on living trees is the presence of pitch tubes on the trunks, mixed with reddish borings, or the presence of reddish boring dust in the loose bark and around the base of the trees. Later the fading, yellowish, or reddish condition of the foliage is conspicuous evidence of the barkbeetles' destructive work.

Successful attacks by species 1 to 8 are followed by a rapid death of the trees. The leaves fade in a month or two and turn yellow and reddish before winter. Successful attacks by species 9 to 11 are followed by a slow death of the trees. While the trees attacked during the summer will have the bark on the trunks killed, the leaves will not turn yellow until the following May.

Attacks by species 12 and 13 are not as a rule indicated by pitch tubes, but the reddish boring dust in the crevices of the bark, in the loose bark, and around the base of the trunk of Douglas fir or larch is quite conclusive evidence of their presence. Douglas fir attacked in the summer will have the leaves fading and turning pinkish in the fall and winter, and reddish in the spring. The leaves on the larch probably fall before they fade, although some of them may remain on the trees after the normal time for them to fall.

In species 14 and 15, pitch tubes and red boring dust, mixed with resin, on the trunk and around the base, are evidences of attack. The trees attacked in the early summer will shed their green needles before fall. Those attacked later in the summer will have the bark on the trunks killed before winter, but the leaves may remain green until growth starts in the spring, when they will fall. Thus in May and June one often finds the ground beneath the infested trees covered with the green needles. After the leaves have fallen the bare twigs will cause the tops of infested trees to present a reddish appearance.

Species 18 to 20 appear to confine their attack to or toward the base of the trees, where large pitch or gum tubes are formed, indicating their presence. In Europe, species 21 sometimes attacks the

trunk at points some distance above the base, where the large pitch or gum tubes indicate their presence.

Species 22 and 23 nearly always attack the base of the trees, where the very large pitch tubes and masses of pitch indicate their work. When the main trunk is infested by these species to a sufficient extent to kill the trees, the evidence of infestation is found in the large pitch tubes and yellow foliage of the dying trees.

SEASONAL HISTORY.

The important features in the seasonal history of these beetles are the hibernation or overwintering of the broods, the beginning of activity in the spring, the emergence and flight of the adults, the beginning and ending of the period of principal attack, the period of larval development, the principal period of transformation from the larvæ to the pupæ and adults, the beginning and ending of the period of emergence, and the number of generations annually.

Certain features in the seasonal history of all of the species are similar, but as a rule each species or series of closely related ones has peculiarities which are more or less distinctive. A knowledge of these facts, therefore, is of prime importance as a basis for advice relating to the exact species involved in a given trouble and the successful methods of control.

The broods of all of the species pass the winter as adults and larvæ in the bark of the trees, logs, or stumps attacked during the preceding spring, summer, or fall. All excavate galleries through the inner living bark in which to deposit eggs, and the larvæ of all feed on the inner bark; all become more or less active as soon as the weather conditions are favorable in the spring, especially the larvæ and overwintered parent adults, the former extending their larval mines and the latter their egg galleries. The principal differences in seasonal history are brought out in the following references to the general features of the different species and in the detailed discussion under each species farther on.

In species 1 and 2, under average conditions, there is one complete generation and a partial second during the season of activity.

In species 1 the first attack is made during the last week in June and first week in July, and the more advanced broods develop and begin to emerge about the last of August, but are not all out before cold weather. The first eggs of the second generation are deposited about the first of September, but the broods do not develop beyond the larval stage before hibernation begins in October. In species 2 the seasonal history is practically the same as in species 1, except that the attack and subsequent stages begin a month earlier. The attack begins during the last of May, and the advanced broods begin to emerge during the latter part of July.

In species 3 there is but one generation annually in the more advanced broods, while the more retarded ones may pass through two winters before they complete their development and emerge. The adults begin to emerge, attack other trees, and deposit eggs toward the last of June, but the broods do not develop before hibernation begins in the fall.

Species 4 has two or three generations annually in its northern range. In the intermediate range, represented by Tryon, N. C., there are three or four generations, while in the more southern range there may possibly be five generations, with activity continuing during the warmer days of winter. Under average conditions the first attack is made about the middle of May, and under favorable conditions the resulting brood develops to adults and emerges in about sixty days.

Species 5 evidently has a seasonal history similar to species 2

In species 8 there is but one generation annually. The attack begins in June, and the broods do not emerge until the following June to August, or later.

In species 9, 10, and 11 there is but one generation annually, and the seasonal history of each is quite similar to that of the others. The first attack is made during the last week in July or first week in August, and the broods do not develop and emerge until the following July and August.

In species 12 and 13 there is a single generation annually. The first attack is made in April to May, and the broods emerge the following April to July.

In species 14 and 15 there is but one generation annually. The first attack is made in June, and the broods do not emerge until the following June to August. In species 17 the attack begins a month earlier. In the European species (No. 21) the first attack is made in May and June, and the broods emerge the following May to August.

In species 22 and 23 there is but one generation annually. The attack is made during the first warm days in March to April, and the broods emerge the following March to September, or later.

INFLUENCES OF LATITUDE AND ALTITUDE ON SEASONAL HISTORY.

The beginning and ending of the hibernating period vary somewhat among the different species, and in each species there is considerable difference at different latitudes and altitudes within its range. Within the area of a given State or section of the country this difference in the beginning or ending of a given period in the seasonal history of a species can be estimated after the date of beginning is determined for a given season in a given locality. In the spring of a given year the average difference in the time of beginning activity, emergence, flight, attack, etc., at the same altitude, will not vary much from four days later for each degree north, or four days earlier for

each degree south, while at the same latitude there will be a difference of about four days for each 400 feet difference in altitude—four days later for each 400 feet higher, and four days earlier for each 400 feet lower. Thus a difference of 7½ degrees of latitude at the same elevation would mean a difference of about thirty days in the beginning of activity or any other event, depending on a given average temperature, while a difference of 3,000 feet in altitude at the same degree of latitude would cause an equal difference in these phenological events.

In the fall of the year the beginning of hibernation and other events will be earlier northward and later southward at localities of the same elevation, or earlier at higher altitudes and later at lower altitudes in the same latitude.

Of course there are exceptions to these rules, especially in regions like that of California, where remarkably abnormal conditions as to influence of altitude and latitude prevail, as also in the case of southern and northern exposures, sandy dry soils, and wet clayey soils or bogs. In such cases the estimates must be corrected so as to allow for three or four days later for the beginning of activity, etc., under average colder conditions, or three or four days earlier for average warmer conditions. The best indication of the rate of difference between two localities is found in the average difference in the dates of opening of the buds or flowers of some indigenous species of forest trees common to both localities, and especially of a species of conifer subject to the attack of a given Dendroctonus beetle.

A knowledge of the facts relating to this principle is of especial importance as a basis for recommending or executing beetle-control policies, since *success depends largely on a knowledge of the proper time to begin and end certain timber-cutting or barking operations for the destruction of the broods of the beetles.*

When, as is usually the case, the seasonal-history data have been collected at different latitudes and altitudes within the range of the species, the discussion under each species is based on a probable average. But when the data have been collected in one locality the discussion relates to that locality, and the probable differences are estimated for other localities. While there is yet much to be determined in regard to the rate of difference between different localities at the same latitude or elevation in the same region and the influence which different latitudes and altitudes exert on different species, sufficient evidence is at hand regarding some of the species of this genus and the regions occupied by them to warrant certain preliminary conclusions as a basis for action and further study.

HABITS.

HABITS OF PARENT ADULTS AND OF IMMATURE STAGES.

All of the species of Dendroctonus will breed to a greater or less extent in the living and dying bark of stumps and logs, and in injured and weakened trees. Some of them show a preference for trees in weakened condition, while others show a preference for healthy trees. *All of those studied, however, have demonstrated their ability to attack healthy trees and kill them whenever the individuals of a species occur in sufficient numbers to overcome the resistance of the tree.* The habit of swarming, or of congregating in one locality and concentrating their attack on groups of trees within a forest, is one of the more striking features in the habits of these beetles. The part of a tree selected for the attack varies somewhat in the different subdivisions of the genus. The species that are more destructive to the life of a tree attack the middle to upper portion of the trunk, while those that are less destructive attack the trunk toward the base, or even at the roots. The beetles' power to resist the repelling effects of the resin that flows into the freshly excavated entrances and galleries in the living bark and to dispose of it by forming pitch tubes at the entrances is most remarkable. This alone demonstrates the ability of these insects to overcome the resistance exerted by a living, healthy tree. The manner of excavating the egg galleries and the directions followed in their extension are quite different among the several species and have a different effect on the tree. The almost transverse, very winding, and closely arranged galleries of species 1, 2, 4, 5, and 6 serve to quickly girdle and kill the trees, while the straight, longitudinal course and parallel arrangement of those of species 9, 10, 11, 13, and 14 result in a much slower, but none the less certain, death of the tree.

RELATION OF HABITS TO SUCCESSFUL CONTROL.

The habits of the broods of larvæ are of special importance in indicating methods of control.

In subdivision A the larvæ of species 1, 2, 5, 6, 7, and 8 excavate their larval mines through the middle layers of the inner bark, so that they are rarely exposed in the inner bark. Those of species 3 and 4 are exposed, but in all of the species of subdivision A the transformations from the larvæ to the pupæ and adults are almost entirely in the outer corky bark, so that in order to destroy the broods of the species of this subdivision the simple removal of the bark is not sufficient; it must be burned or otherwise destroyed.

In the species of subdivisions B, C, and D the larvæ excavate their mines in the inner layers of bark and also transform to pupæ and adults in the inner bark, so that when the bark is removed from the

tree they are exposed to the frost or sun and drying winds, which is sufficient to kill them, without the necessity of burning the bark.

It will be seen from the foregoing that the periods in which control operations must be conducted are indicated by the habits and seasonal history of the species involved. In general, the work should be done between the beginning of hibernation in the fall and the beginning of activity in the spring, but in the case of certain species in which there are one or more complete generations within the season of activity, such as species 1, 2, and 4, it may be desirable under certain conditions to dispose of the infested trees during the summer, as well as during the winter, especially during the principal development and summer activity of the first generation of larvæ. In the case of species 9, 10, and 11, the operations may be continued after activity begins in the spring until late in June or the first of July.

SECONDARY INJURIES TO THE TREES.

Some of the losses resulting from secondary injuries or destruction may be mentioned in this connection. One of these which affects the commercial value of the beetle-killed trees is the bluing of the sapwood. This, according to Dr. Hermann von Schrenk, is due to a fungus which finds its way into the wounds and galleries made by the beetles and rapidly penetrates the sapwood to the heartwood, causing at first bluish streaks and later a uniform bluish-gray appearance of the wood. This bluing condition, especially in pine trees infested with species 9 to 11, often prevails long before the leaves of the beetle-infested trees show evidence of decline or death.

Other secondary losses consist in abnormal decay of the sapwood and heartwood, but the greatest losses of this class may come from forest fires started in the beetle-killed timber, which may not only complete the destruction of the old dead and the newly infested timber, but also spread into the healthy forests. But there is one redeeming feature in the destruction of the beetle-infested timber by fire, and that is the widespread destruction of the beetles in the infested trees, thus preventing the rapid extension of their ravages which would otherwise occur.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLES.

It is quite necessary that we should have some general and detailed information in regard to the influences upon the beetles of climate, fires, etc., and how certain methods and practices in the management of a forest, or in utilizing its resources, contribute to the multiplication of the destructive enemies of the living timber, and how certain other methods may contribute to their reduction or destruction. There is considerable difference in this respect between different sections of the country and between different species of Dendroctonus, as mentioned under the more detailed discussion of the several species.

CLIMATIC INFLUENCES.

DROUGHT.

It is the common impression that the death of pine and spruce timber in certain sections of the Rocky Mountain region is primarily due to a weakened condition resulting from drought and that the work of the insects is secondary. Under the influence of exceptionally severe drought during several successive seasons this may be true to a very limited extent, but our observations lead us to conclude that drought does not offer specially favorable conditions for the multiplication and destructive work of barkbeetles. In fact, the reverse is more likely to be the rule, since exceptionally dry conditions appear to be more unfavorable for the development of the beetles than humid conditions. The only exception we have noted in which injury is greater in dry sections than humid ones is that of the Douglas fir. In the more southern range of this tree, where the normal dry character of the climate and soil prevails, it suffers more from the Douglas fir beetle (No. 13) than it does in the Northwest, where, under moist conditions and rich soil, the tree reaches its best development. This beetle is very abundant in the Northwest, yet as a rule it confines its attack to the felled and injured timber and rarely attacks the healthy trees. On the other hand, the western yellow pine suffers more severely in the humid sections than it does in the more arid ones, as demonstrated by the work of the Black Hills beetle (No. 10), which is widely distributed over the eastern section of the Rocky Mountain region, yet has been far more aggressive and destructive in the Black Hills National Forest than in the much drier sections in southern Colorado and northern New Mexico and Arizona, and has continued its depredations in the Black Hills unabated through excessively wet as well as excessively dry seasons.

The western pine beetle (No. 1) is far more abundant and destructive in the northern and more moist climate of the mountains of Idaho, Oregon, and California than is its near relative, the southwestern pine beetle (No. 2) in the drier forested areas of New Mexico and Arizona. The mountain pine beetle (No. 9) is exceedingly destructive to the lodgepole pine at high altitudes and under especially moist conditions. The same may be said of the eastern spruce beetle and the Engelmann spruce beetle. It is evident, therefore, that drought is not an important factor in contributing to the multiplication or destructiveness of this class of enemies.

LOW TEMPERATURE AND SNOW.

While the severe cold at the high elevations in which most of the western species prevail appears to have no detrimental effect on the overwintering broods, we have a striking example of its effect on a northern migration of a southern species, in the complete extermination of the southern pine beetle (No. 4) in the Virginias by the exceptionally cold winter of 1902–3. On the other hand, snows, when sufficiently heavy to break down a large amount of timber, might offer favorable conditions for the multiplication of some of the species like the western pine beetle, the mountain pine beetle, and the Douglas fir beetle.

LIGHTNING.

In certain sections of the country where a great many pine and spruce trees are struck by lightning during the summer months these trees furnish exceptionally favorable conditions for the perpetuation and multiplication of the pine and spruce beetles. Although the constant supply of such trees furnishes also favorable conditions for the multiplication and perpetuation of the natural enemies of the destructive beetles (insects and birds), these enemies are frequently not sufficiently numerous to serve as a natural check, and the living timber is attacked by the broods of beetles which develop in the lightning-struck trees. This is especially true in the Southern States, where a pine tree struck by lightning attracts the beetles to the spot, and they not only enter the injured tree but attack and kill a number of those surrounding it.

WINDSTORMS.

Whenever a windstorm occurring during the period from June to August is sufficiently severe to fell and break a large amount of pine and spruce, favorable conditions may be presented for the multiplication of certain of the destructive beetles, provided they are present in the locality in sufficient numbers to infest the felled timber. This has been demonstrated from time to time in Europe, where beetles with much less aggressive habits than the Dendroctonus beetles have, it is said, been thus enabled to multiply to sufficient numbers to attack and kill the living timber and cause serious extension of their depredations into the healthy forest.

OTHER INFLUENCES AND CONDITIONS.

FOREST FIRES.

While some of the species find favorable conditions for their multiplication in fire-scorched trees, others, like the Black Hills beetle, appear to prefer the uninjured trees. This is due, perhaps, to the fact that if a fire be sufficiently severe to kill large pine trees, the bark on the lower and middle trunk is so scorched and killed that the beetles can not live in it. Spruce, however, may be killed or weakened from injuries to the base and roots by a surface fire, and thus offer especially favorable conditions for the multiplication of the spruce beetles. On the other hand, a forest fire in a forest in which the majority of the trees are infested by broods of beetles and dying from their injuries may contribute to the destruction of the insects and the protection of the remaining living timber.

MATURED TIMBER.

Practically all of the more destructive species show a decided preference for the larger and best-matured trees, and as a rule these are killed first, and the younger timber is not attacked until later, if at all. This is particularly true of the spruce beetles (Nos. 14 and 15), the southern pine beetle in the East and South, the western pine beetle, and the mountain pine beetle of the West.

COMMERCIAL CUTTING.

The cutting of living timber for commercial purposes may offer favorable conditions for the multiplication of some of the species, like the Douglas fir beetle and western pine beetle, but if such cutting, within a range of less than 50 square miles, is more or less continuous, it appears to serve as a protection to the living timber rather than otherwise. On the other hand, local sporadic cutting may bring about more or less serious results. Some species, like the Black Hills beetle, are evidently not attracted from the living trees by cutting operations, while the southern pine beetle in the Southern States is greatly favored by sporadic cutting, especially if carried on during the summer months.

SUMMER CUTTING.

The cutting of healthy trees, or even of living beetle-infested trees, during June, July, and August, in a forest or section where the southern pine beetle, the western pine beetle, the mountain pine beetle, or even the Black Hills beetle, is present, is more or less objectionable from the fact that the beetles are attracted by the odor of the exposed bark and wood and often attack many healthy trees in the immediate vicinity of the felled ones.

WINTER CUTTING.

When any of the more destructive beetles are present in a forest it is important that the principal timber-cutting operations should be carried on during the late fall and winter months, and completed in the spring before the beetles begin to fly. This is especially important when there is a large amount of infested timber to be utilized, because it is necessary to remove the bark from the trunks

of such trees or convert them into lumber and burn the slabs before the insects begin to emerge. Winter cutting of living, healthy timber is much to be preferred when species with a single generation, like the mountain pine beetle, Douglas fir beetle, or the spruce beetles, are present, because during the following summer the stumps and slash will serve to attract the beetles away from the living trees. And since the broods would remain in the bark during the following winter they can then be destroyed by burning the slash any time during the following fall or winter. In the Southeast and in the Rocky Mountain region, however, when species with more than one generation annually are present, it may be necessary to burn the winter slash before the first of July, to destroy the broods of the first generation which develop from eggs deposited during May or June.

NATURAL ENEMIES OF THE BEETLES.

Were it not for the natural checks and control of some of the insect enemies of forest trees, the destruction of the forests would evidently be far more continuous and complete, but under the existing warfare between the trees and the destructive beetles and between the beetles and their own enemies, a more or less balanced condition in nature is preserved, so that it is only under exceptional conditions that a species of tree or a species of insect is exterminated.

INSECTS.

The insect enemies of the destructive beetles consist of parasites, predators, and robbers. The parasites are small wasplike insects.[a] The adults lay their eggs on, in, or near the beetle larvæ, and the minute maggotlike larvæ of the parasite, situated either internally or externally, feed on the body fluids and thus cause the death of their victims. When the parasite larva reaches its full development it either changes to a free pupa in the mine of its victim or makes a cocoon in which it goes through its transformation. Therefore the presence of certain of the parasitic enemies of the beetle larvæ is indicated by the presence of their cocoons in the mines, even after their victims have been destroyed and they themselves have emerged.

The principal predators consist of certain adult beetles and their larvæ[b] (see fig. 32), the adults often feeding on the adults of the destructive beetles before or after they enter the bark, and the larvæ feeding on the broods of the beetle larvæ in the bark.

There is another class of predatory enemies of the beetles among the true bugs,[c] which follow the beetles and larvæ into their galleries

[a] Order Hymenoptera, families Braconidæ, Chalcididæ, etc.
[b] Order Coleoptera, families Cleridæ, Histeridæ, Trogositidæ, Colydiidæ, etc.
[c] Family Anthocoridæ.]

and mines, and kill their victims by inserting their beaks into their bodies.

The so-called robbers (see fig. 30) consist of large bark-boring grubs or larvæ of long-horned beetles,[a] which sometimes rob the barkbeetle larvæ of their food supply or kill them outright, by destroying the inner bark before the broods of barkbeetles have completed their development. These, however, do not occur so commonly with the more destructive barkbeetles as with those which, like the bark-boring grubs, are in the bark as the result, and not the cause, of the dying condition of the tree.

While some of the Dendroctonus beetles have numerous insect enemies, others have comparatively few. Some of the smaller species, like the southern pine beetle, which often occupy the thin bark on the upper portion of the trunk and branches of the larger trees, and sometimes on young trees, have many parasitic enemies, while others of the small species, as 1, 2, and 5, and the larger species, such as the Black Hills beetle and the Douglas fir beetle, which usually occupy the thick bark, have none at all, or very few.

So far as determined, the southern pine beetle has 11 parasitic and about an equal number of predatory enemies; the eastern spruce beetle has 5 parasitic and 4 predatory enemies, and the eastern larch beetle 6 parasitic and 2 predatory enemies. Of the western species the mountain pine beetle is the only one on which a parasite has been found, but there are four or five predators common to all, which evidently exert quite an important influence in protecting the forests of some sections. With a little assistance on the part of the owner of the forest, this class of beneficial insects will exert a much more powerful influence in preserving a desirable balance among the contending forces, and thus prevent destructive outbreaks of the beetles. This balanced condition appears to prevail at the present time within the range of the southern pine beetle, and with proper attention to local outbreaks of the beetles it could be maintained. However, this whole subject of parasites and predatory enemies of forest insects and their economic relations is one which has not as yet received the attention it deserves. Mr. Fiske gave the matter considerable attention during his field work in forest insect investigations, but his detail to another branch of the Bureau prevented him from continuing it.

BIRDS.

Wherever the Dendroctonus beetles have been found in standing timber the work of woodpeckers has been more or less common, and in some trees quite a large percentage of the beetle broods has been destroyed by the birds. The evidence gathered in Maine a few years

[a] Family Cerambycidæ.

ago indicates quite conclusively that the birds were rendering a most valuable service as a natural check to the multiplication and destructive work of the eastern spruce beetle. The work of birds is common in sections where species 1, 9, and 10 and other western species are prevalent. Yet birds evidently render the greatest service where but few trees are being killed, since their concentrated work may prevent an abnormal increase of the beetles; but where many hundreds or thousands of trees are being killed, the limited number of birds can have little or no effect. Therefore, while the birds are among the foresters' valuable friends, they can not, even with the utmost protection, always be relied upon to protect the forest from its insect enemies. We must remember that there are most complex interrelations between birds, the injurious insects, the beneficial insects, the enemies of the birds, etc., which do not always result in benefit to the forest. In fact it is often quite the reverse. Therefore, in order for the forester or owner of the forest to derive the greatest benefit from the conflict, he must not only direct his efforts toward utilizing as far as possible the natural factors which are contributing to his personal interests, but whenever the enemies of the forest threaten to get beyond natural control he must enter the fight and by radical artificial means force them back to their normal defensive position.

DISEASES OF THE INSECTS.

While evidence has frequently been found of the work of fungous or bacterial diseases in destroying the adults and immature stages of the beetles, the matter will require detailed study by specialists on such diseases before any definite conclusions can be formed in regard to their economic relations or importance.

DISEASES OF THE TREES.

Evidence has been found from time to time that the primary cause of the death of isolated large and small trees and saplings was some fungous disease of the roots and base of the stem, and that the larger trees so affected sometimes favored the multiplication of a destructive insect enemy. Evidence has also been found that certain diseases of the inner bark and sapwood, like the bluing fungus studied by Dr. Hermann von Schrenk,[a] are sometimes very injurious and destructive to the developing broods of the beetles. It is also apparent that this fungus, which is said to depend largely on the wounds made by the beetles in finding its way into the living bark and sapwood of the standing timber, may also contribute to the more rapid and certain death of the trees. Therefore this interrelation between plant diseases and insects must often be considered in our efforts to locate the primary cause of a trouble.

[a] The "Bluing" and the "Red-Rot" of the Western Yellow Pine, with Special Reference to the Black Hills Forest Reserve. By Hermann von Schrenk. Bul. 36, Bureau of Plant Industry, 1903.

It has been conclusively determined, however, that *when the beetles occur in sufficient numbers, they are entirely independent of the aid of other factors or the influence of their enemies, and that they attack and kill perfectly healthy timber over extensive areas.*

SECONDARY ENEMIES OF THE TREES, AND DEPENDENTS, GUESTS, ETC., OF THE DESTRUCTIVE BEETLES.

As soon as the attack of one of the destructive beetles causes a weakened or dying condition of a tree, such a tree becomes at once the breeding place of many other species of barkbeetles and bark and wood boring grubs which can not attack healthy trees. These secondary enemies of a tree are dependent on the more aggressive Dendroctonus beetles or on other factors that may cause a similar weakened or dying condition of the trees. Some of them render special service to the destructive beetles by attacking the twigs, the branches, and the unoccupied bark on the upper and lower portions of the trunk, and thus aid in bringing about the certain death of the tree. There are some insects which live in the galleries with the adult beetles, in the relation of guests, others as scavengers, etc., so that it is always important to distinguish which are the real primary enemies, which are secondary, which are beneficial, and which are neutral in their relation to an affected tree.

GENERAL METHODS OF CONTROL.

While the subject of control is treated under the special discussion of each species, there are some general principles and features which should be mentioned in this connection, especially such as relate to the infestations of standing timber by the broods of the destructive beetles.

HABITS AND SEASONAL HISTORY AS SUGGESTING METHODS OF CONTROL.

Any systematic plan or method for the destruction and control of these beetles, in order to be least expensive and most successful, must be based on a knowledge of the habits and seasonal history and many other essential features relating to the particular species, or group of allied species, involved in a given problem. The principal facts of importance in this connection are as follows: (*a*) It is the normal habit of all of the species to infest the bark on the main trunk of the larger to medium sized trees; (*b*) in all species the developing broods of larvæ live in the inner bark; (*c*) some of the species, as in subdivision A, enter the outer dry bark to transform to adults,

while others, as in subdivisions B, C, and D, transform in the inner bark; (*d*) the broods of all of the species pass the winter in the bark of the infested trees and remain there until they develop to the winged stage, when they leave the then dying or dead trees to fly and attack the living ones; (*e*) the developed broods of beetles usually emerge from the trees before the leaves are all dead, or certainly by the time the leaves have all changed to the reddish-brown color and begin to fall or have entirely fallen from the branches. (See fig. 25.)

DESTRUCTION OF THE BROODS.

Since the trunk of the tree is the principal part of attack, we have only to direct our efforts to the infested bark on the main trunk, and adopt the method of killing the broods which, under local conditions and facilities, is the most practicable and efficient.

In species 1 to 8 removing the infested bark, and burning or otherwise destroying it, is necessary to kill the developed broods of larvæ, pupæ, and adults which may be located in the outer bark.

In species 9 to 23 the removal of the infested bark without burning is all that is necessary. The time to do the work in both cases is from the time activity ceases in the fall until two or three weeks before the normal time for the winged adults to begin to emerge and fly.

BARKING THE STANDING TREES TO KILL THE BROODS.

The bark may be removed from the standing trees by means of suitable tools (see figs. 57, 58), and the trees left until it is convenient to fell and utilize them. Thus, during the period in which these operations must be done, the labor should be directed exclusively to the removal of bark. If necessary, the barked trees may be left standing for several years without the value of the wood becoming impaired; otherwise their utilization may immediately follow the completion of the barking operations. Whenever the conditions are favorable for the immediate disposal or utilization of the infested timber by sale, free use, or otherwise, the timber may be barked as it is felled and the barked log may be converted into lumber at any time during the year, within the required period.

DESTRUCTION OF THE BROODS WITHOUT REMOVING THE BARK.

The destruction of the broods without removing the bark may be accomplished by several different methods: (*a*) By converting the logs into lumber and burning the slabs; (*b*) by placing the logs in water; (*c*) by piling the trunks and scorching the bark sufficiently to kill the broods; (*d*) by scoring the upper side of the felled trunks to allow the water from rain or melting snow to penetrate the inner bark and thus destroy the broods; (*e*) by transporting the infested trunks a sufficient distance (20 to 50 miles or more away) from the forest and away from any living spruce or pine, so that the beetles emerging from them will find no trees to attack.

ATTEMPTS AT COMPLETE EXTERMINATION OF THE BEETLES UNNECESSARY.

As a rule, it is not only useless but unnecessary to attempt the complete extermination of one or more species of the beetles within a given forest. It is necessary, however, to so reduce and weaken their forces that they can not continue an aggressive attack, thus leaving them to depend upon weakened and felled trees for their support and to occupy a defensive position against their natural enemies.

It must be kept in mind that the beetles must occur in great numbers in order to be successful in their attack on healthy trees. If their number is reduced and kept below that required for killing trees they can do no harm. Therefore in the case of a destructive outbreak it is necessary to destroy only from 50 to 75 per cent of the beetles in order to bring them under complete control.

REQUISITES FOR SUCCESSFUL CONTROL.

The principal requisites for success in dealing with these beetles are: (*a*) Prompt recognition of evidences of their presence before they have extended their depredations beyond a few scattering clumps or patches of trees; (*b*) positive identification of the species involved; (*c*) prompt action in adopting the proper method of control; and (*d*) reliance on expert advice relating to the essential features in the habits and seasonal history of the insects, on which the action is based.

HOW TO CHECK AND CONTROL AN EXTENSIVE INVASION.

If the depredations by species 9, 10, 13, 14, or 15 have spread over a large area and there is yet a large amount of living timber or adjacent healthy forests to be protected, a careful survey should be made in September, October, or November, for the purpose of locating the areas and localities of new infestation in which the trees were attacked during the summer and fall and which, at the time of survey, contain living broods. The areas of principal infestation and the larger patches of infested trees should be designated on a map, and estimates made of the total amount or percentage of timber affected. This will form a basis for definite plans and the organization and equipment of a sufficient force to do the required work within the specified time designated for each species. Then, if regular logging

operations can be directed and concentrated upon the principal areas so that a large percentage of the timber can be cut, barked, or otherwise treated before the broods begin to emerge, the desired control may be effected with little additional expense, or even at a profit. If this method can not be adopted, the force should be directed to removing as large a percentage as possible of the infested bark from the standing infested trees or from those felled for that purpose. The first work should be done in the principal areas and larger patches. The work should be planned and executed with the object of destroying the greatest possible number of broods for the time and labor involved; that is, if there are more infested trees than can be barked within the specified time, and five or six times as many insects can be killed by removing half of the infested bark from three or four trees as could be done in the same time by removing all of the infested bark from one tree, the former procedure is far preferable.

HOW TO CONTROL A LIMITED ATTACK.

Whenever it is determined that one or more species is attacking and killing small patches of timber in a given locality or forest of greater or less extent and that the bark of the living and dying trees contains living parent adults and developing broods, prompt and, if necessary, radical action should be taken before the adults begin to emerge and fly.

HOW TO MAINTAIN CONTROL.

IN STATE AND NATIONAL FORESTS.

In State and National forests, and in all other forests in which there is an organized force of rangers and fire wardens or patrols, each officer should be furnished with the necessary instructions for the location of beetle-infested trees and with equipment and directions for taking the necessary action whenever the conditions demand it. It has been demonstrated that any intelligent ranger or manager can become proficient in locating and marking infested trees with comparatively little instruction in addition to that already published or conveyed in special recommendations.

It is not necessary that every isolated infested tree should be treated, but it is of especial importance that all groups of infested trees should receive prompt attention.

IN PRIVATE FORESTS.

Private forests should receive the same attention as reserves, but this is often far more difficult on account of intervening forests, where the owners either can not or will not give the matter the required

attention. While in exceptional cases it may be advisable to have laws governing the treatment of timber infested with a dangerous pest, such laws should be based on expert advice and should apply to the more extreme and well-known cases only as a last resort. It is probable that in most cases legislation will not be necessary, and that more ultimate good will result without than with such laws, especially when it can be made clear to the owner that his personal interests demand that he take the proper action and that when necessary his neighbors will render assistance, as is done in the case of a forest fire.

INACCESSIBLE AREAS.

There are yet large inaccessible areas in the East and West where it will not be practicable or possible to control the depredations by these beetles, and which therefore must be left to natural adjustment. While under natural control the matured timber will be lost, it will usually be replaced by young growth, so that under normal conditions the forest will be perpetuated. Under exceptional conditions and combinations of detrimental influences, such as insects, fire, and drought, extensive areas may, however, be completely denuded, never to be reforested under natural conditions. This has doubtless happened in very many denuded and bare areas in the Rocky Mountain region, which were at one time heavily forested.

TRAP-TREE METHOD OF CONTROL.

The well-known attraction of many species of European barkbeetles to weakened, dying, and felled trees suggested to some of the earlier writers on forest insects a method of barkbeetle control which since that time has been widely recommended and under certain conditions and for certain species of beetles has been successfully practiced. It is the so-called trap-tree method, in which living trees are deadened or felled at the proper time or season to attract the insects and induce them to breed in the bark, where they can be easily destroyed by removing the latter or burning the entire tree. Experience and observations indicate, however, that while this method is successful in attracting many species of bark and wood boring insects it does not always attract those which are the most destructive to the living trees, or at least not in sufficient numbers to justify its general recommendation and adoption.

Among the Dendroctonus beetles there are a few species which are attracted to weakened and dying trees and to the stumps, logs, and tops of recently felled living trees. These are species 1, 2, 4, 12, 13, 22, and 23 and, to a more limited extent, species 14 and 15, but extensive experiments have indicated quite conclusively that the Black Hills beetle, the most destructive species of all, can not be success-

fully attracted to trap trees and that it actually prefers to attack healthy living trees.

The Mountain pine beetle is attracted to a greater or less extent to felled and fire-scorched trees, but will at the same time attack near-by living ones, as will all of the other species. It is therefore under exceptionally favorable conditions only that this method would be sufficiently successful to warrant its adoption as a means of controlling this class of beetles. These exceptions would be as a rule on a very limited scale, as is referred to under the special discussion of some of the species.

One of the objections to the trap-tree method of combating the Dendroctonus beetles is in the fact that a few living trees deadened or felled in the midst of a healthy forest where the destructive species are present may, as has often been demonstrated, not only attract the beetles to the trap trees but to the near-by healthy trees, thus inducing instead of preventing a destructive outbreak.

INTRODUCTION AND PROTECTION OF NATURAL ENEMIES.

The introduction and protection of natural enemies of these bark-beetles is a subject of special interest and one that should receive attention in the future, especially in the line of investigations and experiments to determine facts on which to base reliable conclusions. In the case of a destructive insect which has been introduced from another country it is plain that if its natural enemies did not come with it they should be introduced; but with native insects it is quite a different proposition and will require much detailed investigation before the results from transfers and introductions can be predicted with any degree of certainty. The protection of natural enemies already present is, however, worthy of special consideration. If, for example, certain parasites and predatory insects are abundant in the bark of the infested trees and certain methods of procedure are adopted for combating the destructive beetles which will at the same time allow the beneficial insects to escape, it will naturally operate against the enemy. But if, on the other hand, the beneficial insects are destroyed along with the destructive ones it may have the opposite effect.

The parasites usually attack the broods beneath the thinner bark, like that toward the top and on the larger branches of the large trees or the trunks of the small ones. Therefore, whenever the parasites are common, it will be best simply to remove the infested thicker bark and leave the thinner bark for the parasites.

Burning the infested bark on the trees or immediately after it is removed will destroy the beneficial insects with the injurious ones, but if the bark be removed in the early fall or early spring and left for several days before burning (if burning is necessary), many of

the beneficial insects will escape. Or, if it is not necessary to burn the bark, practically all will escape, and thus assist in destroying the broods left in the tops of trees and those in scattering trees. It is always important, therefore, to determine whether or not the natural enemies are present in sufficient numbers to make it worth while to adopt special precautions for their protection.

Wherever woodpeckers are common in a forest they may aid greatly in destroying the broods of barkbeetles in the scattering clumps and isolated trees, especially if the beneficial insects are scarce. If, on the other hand, the beneficial insects are common, the birds may feed on them and do as much harm as good. The protection of the birds, however, should be maintained, because even if they are harmful at times they evidently more than compensate for it in the general service they render to the forest.

IMPORTANCE OF SYSTEMATIC FORESTRY.

After all, success in the control of these beetles and of forest insects in general depends more upon good forest management, perhaps, than upon anything else relating to the practical phases of the problem, for without some organized system of management very little can be accomplished toward the successful utilization of available information or methods of control. It is equally true, however, that unless the available knowledge relating to the insects and the principles of their control is understood and properly utilized in forest management and lumbering operations, nothing will be accomplished, and the depredations and great losses of valuable timber will continue.

SOME RESULTS OF EFFORTS TO CONTROL BEETLE DEPREDATIONS.

It is only within recent years that any detailed work has been done on the forest insects of North America, and the possibility of controlling their depredations is not generally recognized, even among foresters. Organized efforts and definite results were not, therefore, to be expected, yet we have a few examples which may serve as demonstrations of what can be done. In 1900 the eastern spruce beetle was killing a large amount of mature spruce in northwestern Maine. This was investigated and the concentration of the logging operations in the infested sections was recommended. This recommendation was adopted, and with little or no additional expense sufficient numbers of the infested trees were cut the first winter, and the logs floated out in the spring, to check the ravages of the beetles, and, so far as can be learned, up to the present time very little timber has since died in that section as the result of insect attack.

In 1905 the Black Hills beetle was killing patches of timber in the vicinity of Colorado Springs and Palmer Lake, Colorado, as it did in the beginning of the attack in the Black Hills of South Dakota, in 1897, but through the efforts of the late Gen. William J. Palmer and others, sufficient numbers of infested trees were felled and barked on private land and in the adjoining National Forest during 1905 and 1906 to destroy a large percentage of the beetles in the entire vicinity. Careful inspection during the fall and winter of 1906 and 1907 indicates that the pest is now under complete control within a radius of some hundreds of square miles.

The successful control of another serious outbreak of the Black Hills beetle in 1906 on an extensive private estate in southern Colorado was effected through the efforts of the owners in having some 500 infested trees felled and barked within the necessary period to destroy the broods. A large percentage, but not all, of the infested timber was thus treated. This was so successful that not a single infested and dying tree could be found when the area was inspected in 1908. In this, as in the other case, considerable unnecessary expense was involved in the burning of the bark and tops, but the utilizable timber was more than enough to pay all expenses. It is evident that in this case a destructive invasion was prevented, and that more than a million dollars' worth of timber was protected.

The most striking example of success in control of the Black Hills beetle was reported in time for mention in this connection. Mr. W. D. Edmonston, a forest ranger, detailed from the Forest Service to the Bureau of Entomology to work under the instructions of the writer in the location and reporting of evidences of beetle infestation in the National Forests of Colorado and adjoining States, reported in May, 1907, that the pine timber was dying on a large estate not far from Idaho Springs, Colorado, and the adjoining National Forest. He was instructed to make more detailed examinations, after which he reported that some 65,000 feet of timber on the estate were found to be infested by the Black Hills beetle, and that unless the ravages were checked at once the timber not only on this estate but on the adjoining estates and National Forest would be killed. The owner of the property was advised by this bureau to take radical action according to a special recommendation and detailed instructions relating to a necessary control policy. No action was taken, however, before the first of the following July, and therefore not in time to prevent the beetles from swarming from the infested trees and extending their ravages. In December, 1907, Mr. Edmonston was instructed to make another examination of the timber, when he found that his prediction was being fulfilled. He reported that instead of 65,000 feet of infested timber, there was nearly four times as much timber involved in the new infestation, or over 250,000 feet.

The owner was again notified in December, 1907, of the serious character of the outbreak, and the suggestion made that if the logs from the infested trees were converted into lumber and the slabs burned before the next May, it would result in the protection of the remaining living timber. Immediate steps were then taken to carry out the original recommendations. Mr. Edmonston gave instructions to the manager of the estate in locating and marking the infested trees and in the essential features in the methods of utilization to destroy a sufficient number of beetles to check the infestation, and he also marked infested timber on the adjoining estate and National Forest. In May, 1908, Mr. Edmonston reported that the larger clumps of infested trees on the estate had been converted into lumber and the slabs burned, and that those on the adjoining estate and National Forest had been cut and barked. In November, 1908, Mr. Edmonston was instructed to make another inspection of the forest on the estate and surrounding area, and on December 1 he reported as follows:

> Nothing could be more satisfactory than the results obtained by the cutting of the infested timber on the estate. Your recommendations and instructions submitted to the owner, and carefully followed by the manager of the estate, have clearly demonstrated that insect infestation can be controlled and at no expense to the owner of the timber involved; in fact, a very satisfactory price was realized, resulting in a net profit, I understand, of $5 per thousand feet, board measure, on the 240,000 feet cut. This, of course, does not include the profit of the milling operations, but for the logs sold at the mill, after deducting the expenses of cutting and logging. The sawmill was owned and operated by an Idaho Springs firm, and the manufactured article sold in that town. I spent six days on the estate—November 18 to 23. After a very thorough examination of the timber, I found only three infested trees, isolated individuals, over a mile from where the large clumps of infested trees were cut. With the exception of those three trees there is no new infestation on the estate. I also examined the adjoining lands, but no new infestation was observed. The infested trees which I marked in December, 1907, had all been cut and barked. On the Pike National Forest, contiguous to the first-mentioned estate, where, you will remember, I marked some clumps of infested trees, no new infestation was found—not one tree. I found that all the infested trees I marked had been cut and barked. Ranger Kelso had charge of this work, and it has been quite thoroughly done.

This most gratifying result demonstrated two important facts: One, that a very extensive outbreak by one of the Dendroctonus beetles can be controlled without expense, and even at a profit, whenever the conditions are favorable for the utilization of the infested timber; the other, that the essential details, recommendations, and expert advice can be sucessfully carried out by a manager of a private forest and by the rangers of National and State forests. It also indicates quite conclusively that the widespread depredations in the Black Hills National Forest could have been prevented with very little expense to the Government if the matter had received prompt attention in 1901, when the first investigations were made and recom-

mendations submitted. But, through the lack of public appreciation of the importance of the problem at the time, and the lack of sufficient authority and funds later, it was allowed to extend beyond practical control, and in consequence a large percentage of the timber on the entire National Forest has been killed.

DETAILED INFORMATION ON THE SPECIES.

The discussions on the following pages relate to more detailed information on each species.

In the first paragraph, under the English and technical name, will be found a brief summary of the distinctive characters of the species, its seasonal history, habits, distribution, and evidences of attack. This is to facilitate preliminary identification by the reader, and is followed by a more detailed account of the seasonal history, habits, and economic features as a basis for the recommendations and proper application of methods of control, and closed with references to the investigations and identifications on which the statements are based. The fact that the species are discussed more or less independently necessitates some repetition of statements relating to seasonal history, habits, and methods of control. In view of the fact, however, that a bulletin of this kind is used mainly as a reference work, in gaining information on a special insect or subject, as it is required, such repetitions are to a certain extent necessary.

GENERAL EXPLANATION OF DESCRIPTIVE AND OTHER TERMS.

While the illustrations will show the parts designated by technical or semitechnical names, there are other terms used in the discussion of seasonal history, habits, etc., which may need some explanation for the general reader.

Brood.—The term "brood" refers to the progeny of a single pair, or the individuals hatching from the eggs in a single egg gallery.

Generation.—By a "generation" is meant all of the broods that are the offspring of the adults of the overwintering broods, except the overwintered parent adults, which may be parents of the overwintered broods, and also of broods from eggs deposited by them in the spring. Another exception is in the retarded individuals which pass more than one winter in either the larval or adult stage.

All the progeny of the overwintered broods may be said to comprise a complete generation. If all of this progeny complete their development between the time the first eggs are deposited in the spring and the close of the same season of activity, and emerge from the trees, it may be referred to as constituting a complete seasonal generation. If another set of broods develops to maturity from eggs deposited by the adults of the first generation of the season, it will form a complete second generation, and so on. If, however, only

parts of the broods complete their development and emerge during the first season, and the others remain over until the next season, it will be a partial development of a seasonal generation. If all of the broods develop and emerge within twelve months from the time the first eggs were deposited, it is referred to as a complete annual generation.

Hibernation.—The term "hibernation" as here applied relates to the period in the seasonal history of the broods from the time general activity ceases in the fall until the time it begins again in the spring. In southern localities there may be considerable activity (feeding and development) of the broods during the warmer days of winter, so that hibernation used in this connection does not mean that the broods are entirely dormant and inactive, but that for the greater part of the time they are.

Overwintering stages.—The overwintering stages are those of the hibernating broods.

Overwintered broods.—The term "overwintered broods" relates to all stages which have passed the winter in the bark of the infested trees, whether active or not. It is, therefore, a better term to use for the barkbeetles than "hibernated broods."

Activity of overwintered broods.—By the "activity of overwintered broods" is meant the feeding, development, transformation, emergence, flight, etc., from the time general activity begins in the spring among the broods which have overwintered in the bark. This activity may extend over several months and overlap the activity of broods of one or more generations. The parent adults that attack the tree too late in the fall to complete their egg galleries usually continue their work of extending the galleries and depositing eggs when activity begins the following spring. Some of the parent adults that have completed their egg galleries in the fall may also live over winter and excavate new galleries when activity begins in the spring. The overwintered broods of young adults include those that transformed to adults before activity ceased in the fall and passed the winter in the pupal cells where they transformed. These are usually the first to emerge and fly in the spring, but sometimes they remain in the bark until the majority of the broods are fully developed. Among the overwintered broods of larvæ there may be all stages from very young or small larvæ to fully developed ones. The latter will begin activity by transforming to pupæ. The immature larvæ begin their activity by feeding and extending their larval mines. Under normal or favorable conditions, the majority of the immature stages of some species will have completed their development and transformed to adults before the overwintered young adults in the same tree have begun to emerge, so that nearly all of them may leave the trees about the same time, but there are always certain trees

in which the conditions are not so favorable for normal development. There are also broods from eggs deposited by overwintered parent adults, so that the period of development and emergence of all of the overwintered broods is prolonged and irregular. In fact, some of the overwintered individuals of certain species may not complete their development and emerge until the second season of activity. These retarded broods are not of much economic importance, but they introduce an element of confusion in defining the limits of a given generation. On the other hand, periods of normal or principal development, transformation, and emergence of the broods are of especial economic importance, since a knowledge of them is quite essential for successful control.

Seasonal history.—According to the writer's interpretation, the seasonal history of an insect is the history of the broods of the species from the beginning of activity in the spring of one year to the end of the hibernating or overwintering period in the spring of the next year.

Life history.—The term "life history," as frequently employed, is synonymous with seasonal history, but to be more exact it is the history of an individual from the egg to maturity and death, including its natural enemies, environment, or any other phenomena affecting its life.

Egg gallery (fig. 7, etc.).—The egg gallery is the burrow made by the adult beetles, along the sides of which the eggs are deposited.

Larval mines and pupal cells (figs. 19, 22, etc.).—The larval mines are the food burrows made by the larvæ. The pupal cells are cavities excavated by the larvæ at the end of the larval mines, in which to transform to the pupæ and adults.

Food burrow.—A food burrow is one excavated into the living bark by the adult beetles for the purpose of obtaining food.

Entrance burrow (figs. 79, 99).—The entrance burrows are the holes made by the parent beetles through the outer and inner bark preliminary to excavating the egg galleries.

Ventilating burrows (figs. 79, 99).—Ventilating burrows are the vertical burrows located at frequent intervals in the roof of the egg gallery and extending outward to or near the surface. They are utilized by the parent adults as a place in which to turn around, or in which to pack the boring dust, or through which to eject the dust, as the case may be.

Exit burrows or exit holes (figs. 8, 22).—The exit burrows or exit holes are the clear-cut holes in the outer bark through which the adults of the new broods emerge from the tree.

Boring dust (figs. 79, 99, etc.).—The sawdustlike borings ejected from the egg galleries or packed in them and in the larval mines is referred to as boring dust.

Pitch tubes (figs. 8, 9, 100).—The resin or gum expelled by the beetles from the entrance burrows is often formed into more or less regular masses with a hole through the middle, thus suggesting the name "pitch tubes."

Infested trees.—Trees containing living parent adults or developing broods are referred to as "infested trees."

Fading tops.—The fading or noticeably paler green of the foliage of infested trees is referred to as "fading tops."

Sorrel tops.—The yellowish foliage of trees dying from the attack of the beetles is termed "sorrel tops." It must be remembered that a certain number of the older leaves or needles on the healthy twigs die, turn yellow, and fall each year; therefore this normal condition should not be mistaken for an indication of unhealthy conditions. It is only when the needles of the middle and tip of the cluster turn yellow from the base outward that the dying of the tree is indicated.[a]

Red tops.—The term "red tops" refers to the color of the foliage after the tree is dead, and usually after the broods of destructive beetles have emerged from the bark. This reddish-brown of the adhering pine needles may prevail for one year or more after the trees are dead.

Beetle-abandoned trees.—After the broods of the destructive beetles have emerged from the bark of a tree such a tree is referred to as "beetle abandoned."

Black tops (fig. 25).—The condition of the dead trees after all of the needles have fallen and two or more years after the beetles have left them is referred to under the name "black tops."

Broken tops (figs. 26, 27).—After the trees have been dead four or more years and the tops have broken off they are termed "broken tops."

Sap stain or blue sap (fig. 29).—The discolored condition of the sapwood of infested trees before and after the leaves begin to fade is referred to as "sap stain" or "blue sap."

Sap decay.—After the trees have been dead long enough for the sapwood to be decayed, but the heartwood is yet in a sound condition they are termed "sap decayed."

Heart decayed.—The term "heart decayed" refers to the condition after the trees have become unfit for any practical use.

Millimeters and inches.—One millimeter equals about one twenty-fifth of an inch or about four-hundredths of an inch. Two millimeters equal about one line, or about one-twelfth of an inch. To reduce millimeters to inches, multiply by 0.04; to reduce hundredths of an inch to millimeters divide by 0.04. To reduce lines to millimeters multiply by 2; to reduce millimeters to lines, divide by 2.

[a] Needles injured by climatic conditions have the tip dead and the base green.

No. 1. THE WESTERN PINE BEETLE.

(*Dendroctonus brevicomis* Lec. Figs. 6–11.)

The western pine beetle is a rather stout, brownish, cylindrical bark-beetle, from 3 to 5 mm. in length, with head broad and grooved, pronotum punctured and but slightly narrowed toward the head, and elytra with fine rugosities, but entirely without long hairs. (See fig. 6.) It attacks healthy, injured, and felled western yellow pine and sugar pine, and is destructive to living timber in the mountains of California and northward and eastward to Washington and Montana. The adults excavate long, winding egg galleries (fig. 7), through the inner layers of living and dying bark. The white, legless larvæ hatching from the eggs excavate short larval mines in the middle portion of the inner bark, the latter rarely showing on

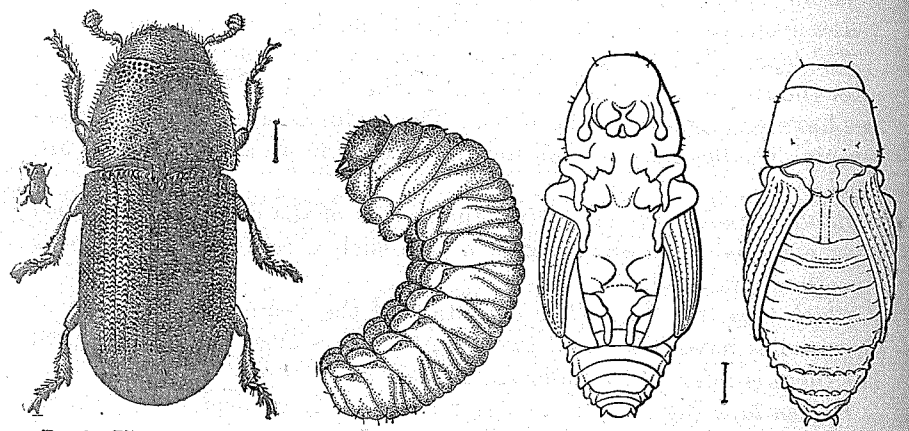


FIG. 6.—The western pine beetle (*Dendroctonus brevicomis*): Adult, larva, pupa, greatly enlarged. (Adult and larva, author's illustrations; pupa, from Webb.)

the inner surface. Later they transform to pupæ and adults in the outer corky bark. Pitch tubes (figs. 8, 9) are produced on the main trunk of the living trees attacked. The fading to yellowish and reddish foliage indicates its destructive work.

SEASONAL HISTORY.

OVERWINTERING STAGES.

The broods pass the winter in the outer bark of trees attacked the preceding late summer and fall, as parent adults, young adults in pupal cases, all stages of larvæ, and possibly pupæ.

ACTIVITY OF OVERWINTERED BROODS.

The overwintered parent adults extend their galleries or excavate new ones and deposit eggs during April and May, from which broods develop and emerge by the last of July to the middle of August.

The broods of young adults in the pupal cells begin to emerge from the trees about the last of June, and continue to come out until the middle or last of August. The broods of overwintered larvæ begin to transform to pupæ about the middle of April and to adults toward the last of April, and the latter begin to emerge from the trees about the middle to last of July, so that practically all of them are out by the last of August, although some of the retarded ones continue to emerge until September or later.

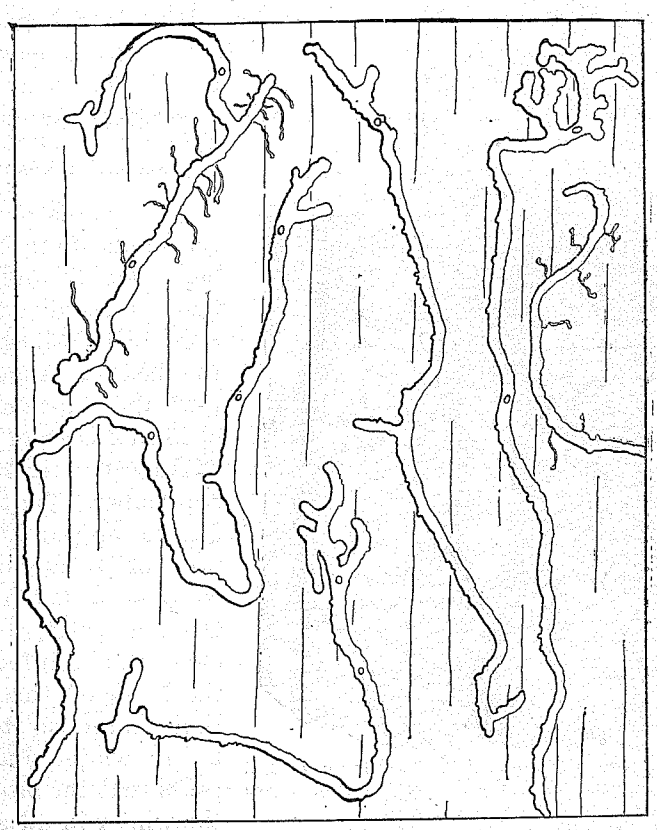


FIG. 7.—The western pine beetle: Egg galleries. Reduced. (Author's illustration.)

FIRST GENERATION.

The overwintered broods of adults begin to attack the trees, excavate galleries, and deposit eggs about the first of July, and continue their activities until September or later. The principal period of attack is during July.

The larvæ begin to hatch in from four to ten days after the eggs are deposited, and may be found in the bark of the same tree from early in July until October, but the principal development is during July and up to the middle of August. They begin to transform to

pupæ about the middle of August, and continue transforming until cold weather, the principal period of transformation being from the middle to the last of August. The pupæ begin to transform to adults after the middle of August, and continue transforming until cold weather, but the principal period of transformation is between the middle of August and the middle of September.

The adults begin to emerge from the trees toward the last of August, and continue to come out until in October, or later, but the principal period of flight appears to be from the last of August to the middle of September. While the majority of the broods of this generation emerge before cold weather, it is evident that some of them overwinter in all stages from larvæ to young and parent adults.

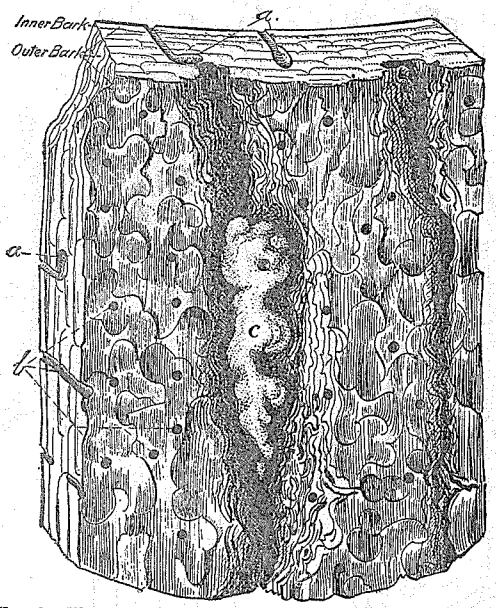


FIG. 8.—The western pine beetle: Bark showing, *a*, *a*, pupal cells; *b*, exit burrows; *c*, pitch tubes. Reduced. (From Webb.)

SECOND GENERATION.

The records of observations indicate that the earlier emerging adults of the first seasonal generation begin to deposit eggs about the last of August, and that the principal period of attack is from the last of August to the middle of September. The larvæ begin to appear about the first of September, and continue to hatch until in October, or later. No evidence has been found that the larvæ of this generation transform to pupæ before winter, but it appears that the broods pass the winter in all stages of larvæ, together with some of the parent adults. Thus, there is one complete generation annually and a partial second one.

HABITS.

The adults attack the living bark on healthy, felled, and weakened standing western yellow pine and sugar pine. They excavate long, winding galleries (fig. 7) through the inner layers of bark, along the sides of which single eggs are deposited at intervals of one-half inch or more. The larvæ normally do not excavate their mines through the inner layers of bark, but through the middle or outer portion of the inner bark. When the larvæ have fully developed, they bore

out into the outer corky bark to pupate and transform to adults. After the adults are fully matured, and the proper time has come for them to emerge, they bore out of the bark (fig. 8) and fly to other trees, there to start a new attack. While very few observations have been made on the habits of flight, it is probable that the beetles swarm during the evening and at night.

ECONOMIC FEATURES.

While it appears that this species prefers to attack weakened and felled trees, or isolated healthy ones, it often attacks large numbers of healthy trees and causes extensive depredations. It is especially destructive to the western yellow pine (see fig. 10) in central Idaho, and in the mountains and higher valleys of eastern Washington, Oregon, and California. It must therefore be classed among the important primary enemies of the pines within its range. As a rule, the largest and best trees are attacked, and the winding egg galleries beneath the bark serve to completely girdle them and cause their death before the broods have developed and emerged.

EVIDENCES OF ATTACK.

The external evidence of attack by this species on healthy trees is the presence of pitch tubes (figs. 8, 9) at the entrance of the galleries, or reddish borings lodged in the flakes of bark on the trunk and around its base. Trees attacked in

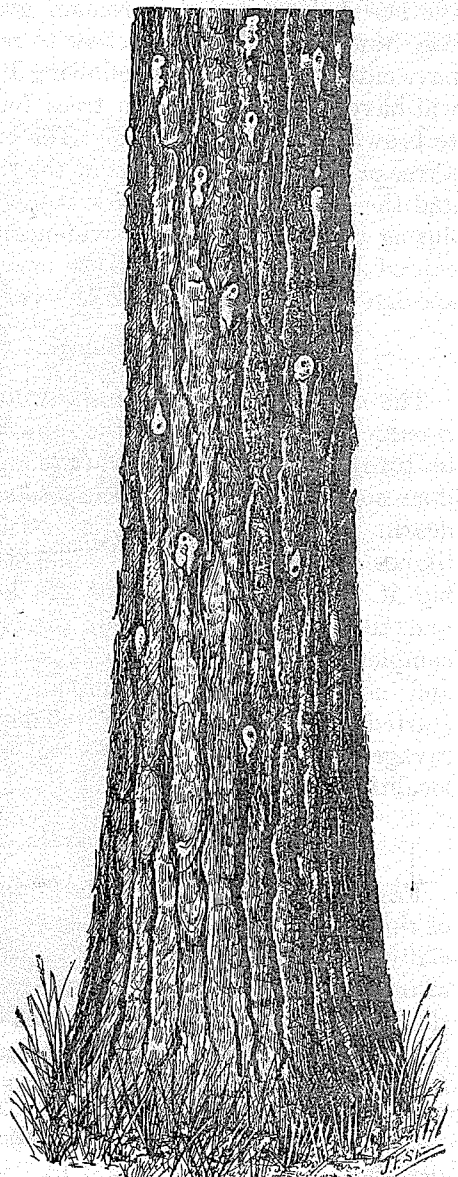


FIG. 9.—Work of the western pine beetle: Pitch tubes on bark of tree. (From Webb.)

July will usually have the foliage fading or turning yellow in August; those attacked in August may have the foliage fading in September and October, while those attacked in September may fade during the late fall or winter or remain green until the following spring. All, however, will have yellow to reddish foliage before the broods have entirely emerged the following July. As a rule, all of the broods will have emerged from the trees found at any season with reddish to brown and falling foliage. The exceptions are when only part of a tree or the bark on one side of the trunk is killed by the first attack, and the remaining living bark is infested later in the same season or during the next. Positive evidence that the above conditions are caused by this species must be based on authentic identification of specimens found in the bark of trees so affected.

EFFECTS ON COMMERCIAL VALUE OF THE WOOD.

The commercial value of the wood of trees killed by this beetle is reduced by the bluing of the sapwood, often before the leaves begin to turn yellow, but the heartwood, especially of the larger trees, does not deteriorate until decay sets in several years after the tree's death. The loss, therefore, is not necessarily very great where the timber is felled and utilized immediately after a destructive attack, but if the insect-killed trees are left standing until the branches and tops break off and fall (fig. 10), the loss is often serious or complete. Serious losses of a secondary nature, both of the dead and adjoining living timber, may often result from forest fires started in the dead timber. Therefore the losses, first from the ravages of this species and second by fire, have been severe in some localities.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication and destructive work of this beetle are found in areas of large, matured timber, and especially where such trees are frequently struck by lightning or injured or felled by storms, etc. The unfavorable conditions for attack upon the living timber are found in areas of vigorous, recently matured, or young growth, and where timber-cutting operations are continued from year to year under modern systems of forest management.

METHODS OF CONTROL.

In localities and areas of greater or less extent where it is known that scattering clumps of trees are dying from the attack of this species, the principal clumps of infested trees should be located in September to March, and the infested bark on the main trunk and larger branches removed and burned, or the logs converted into lumber and the slabs burned. This work should be begun not earlier

than October and should be completed by the first of June. If at least 75 per cent of the infested trees are thus treated, sufficient numbers of the broods will be destroyed the first year to protect the remaining timber for several years. Then, if all patches of infested timber are subsequently located and barked before the broods emerge, it should serve to keep this enemy under complete control.

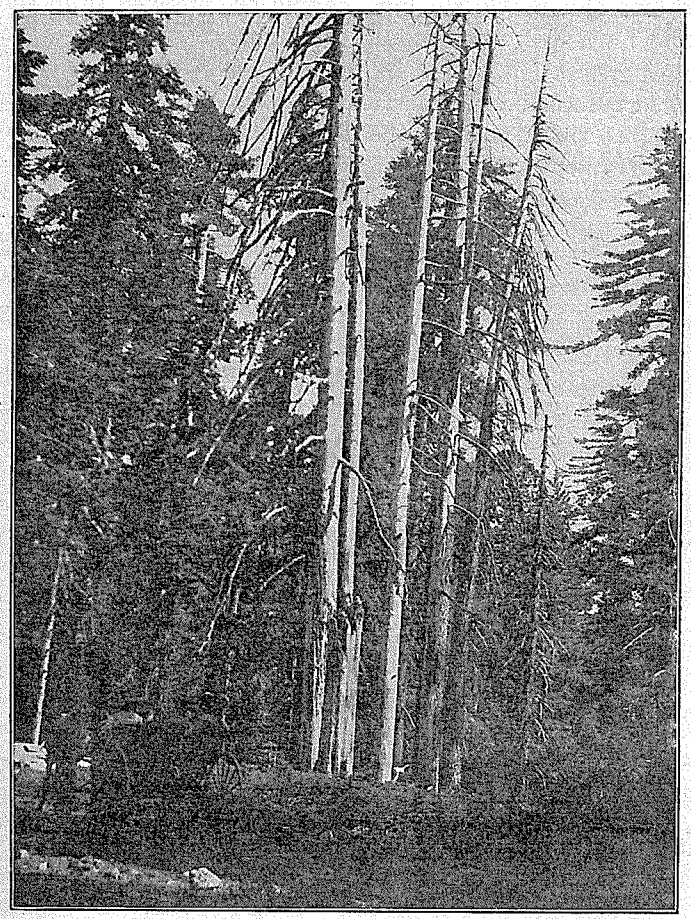


FIG. 10.—Western yellow pine killed by the western pine beetle, Yosemite National Park. (Original.)

Summer operations in the barking of infested trees are not to be recommended, except in special cases where it is desirable to destroy the broods of the first generation. In this case the work should be done during the period of principal larval development—that is, from the middle of July to the middle of August, or when the leaves of the infested trees are just beginning to fade.

It has been determined that this species can be attracted to girdled and felled trap trees. Under certain conditions, therefore—as in the case of the absence of logging operations and where only a few scattering trees are infested—it may be desirable, as a means of maintaining control, to provide a few trap trees to attract the first generation. This can be done by girdling two or three inferior trees to the heartwood or by felling them in June. Then, if they become infested with this beetle, the bark should be removed from the main trunk and burned by the middle of August. Trap trees to attract the second generation should be prepared in August and September and barked before the first of the following May. Usually an average of one to three trees to the acre should be sufficient for this purpose. However, the number will depend largely upon the prevalence of the insect. (See preceding reference to trap trees, pp. 33–34.)

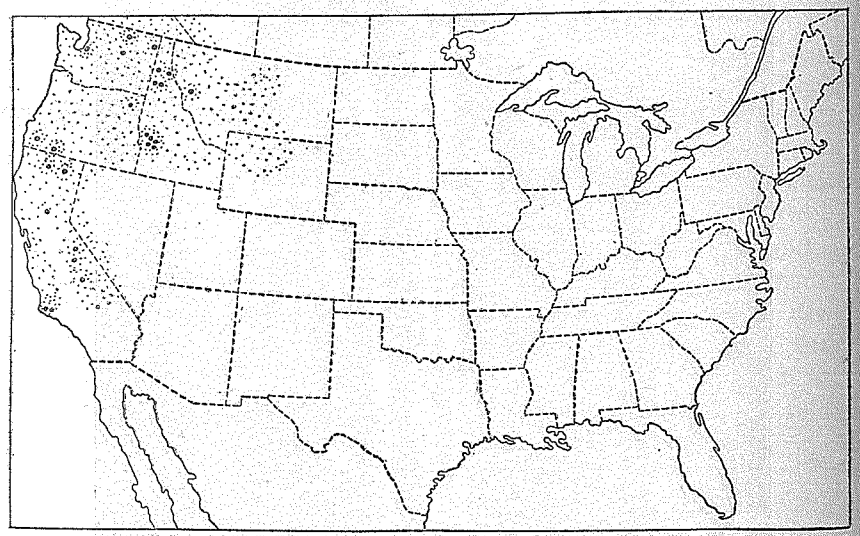


FIG. 11.—The western pine beetle: Distribution map. (Author's illustration.)

Continued timber-cutting operations within an area of from 20 to 50 square miles usually provide sufficient breeding places in the bark of the logs and tops of the felled trees to satisfy the requirements of this species; but if the living timber should be at any time threatened by the broods emerging from the slash, or if it is desirable to include in timber-sale and timber-cutting regulations certain provisions for the burning of the slash, this work should be done about the first of August for the slash of the winter and spring cutting, and during the winter for that of the late summer and fall cutting; the latter period, however, is preferable, on account of the danger of starting forest fires by summer burning.

BASIS OF INFORMATION.

The preceding information on the western pine beetle is based on investigations by the writer at McCloud, Cal., at Grants Pass, Oreg., near Spokane, Wash., and at Moscow, Idaho, April and June, 1899, and in the Yosemite National Park and Yosemite Valley, California, June, 1904; by Mr. J. L. Webb, at Moscow and Troy, Idaho, September and October, 1900, and at Centerville, Stites, Kooskia, Grimes, Placerville, and Smiths Ferry, Idaho, April to September, 1905; by Mr. H. E. Burke, at Smiths Ferry, Idaho, October, 1904, in the Yosemite National Park, at Wawona, and in the Yosemite Valley, California, June to August, 1906, and at Joseph, Oreg., in 1907, and by Mr. V. S. Barber, at Sterling and Chester, Cal., in 1908. Additional localities through correspondence and from other collections are Badger, Ballard, and the Santa Barbara National Forest, Cal.; Winthrop and Auburn, Wash.; Pokegama, Oreg., and Missoula, Mont. The species is represented in the forest-insect collection of the Bureau of Entomology by several hundred specimens.

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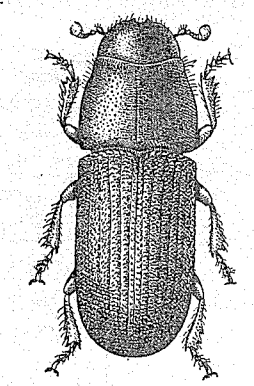

FIG. 12.—The southwestern pine beetle (*Dendroctonus barberi*): Adult. Greatly enlarged. (Author's illustration.)

No. 2. THE SOUTHWESTERN PINE BEETLE.

(*Dendroctonus barberi* Hopk. Figs. 12–14.)

The southwestern pine beetle is a small, rather stout, light to dark brown barkbeetle, from 2.5 to 4.7 mm. in length, with a broad grooved head, sides of the prothorax slightly narrow toward the head, elytra with moderately coarse rugosities, and elytra and declivity without long hairs. (See fig. 12.) It attacks healthy, injured, and felled western yellow pine in southern Colorado and Utah and in the mountains of Arizona, New Mexico, western Texas, and northern Mexico.

The adults excavate winding, transverse, egg galleries (fig. 13) through the inner bark and mark the surface of the wood. The larval mines are rarely visible on the inner surface of the bark, but extend through the middle portion and into the outer corky portion, where the larvæ transform to pupæ and adults. The presence of this species in standing timber is indicated by pitch tubes on the trunk similar to those made by the western pine beetle (figs. 8, 9) and by the fading yellowish to red foliage.

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SEASONAL HISTORY.

OVERWINTERING STAGES.

The broods pass the winter in all stages from young to matured larvæ, young adults, parent adults, and possibly pupæ, in the outer bark of trees and logs attacked by the parent beetles the previous summer.

ACTIVITY OF OVERWINTERED BROODS.

The overwintered parent adults begin to excavate galleries and deposit eggs as soon as warm weather permits in the spring, and continue to do so until about the first of June. The overwintered broods of young adults begin to emerge toward the last of May (northern area) and continue to come out until the last of June or later. The overwintered larvæ begin to transform to pupæ and adults soon after activity begins in April or May, but retarded individuals may not develop until in July, or later. The adults from the overwintered larvæ begin to emerge toward the last of May, and continue emergence through June or until the latter part of July, or later. Probably all are out by the first to middle of August.

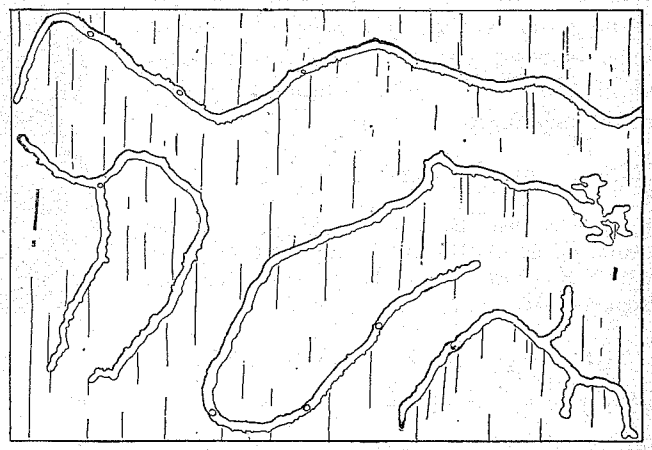

FIG. 13.—The southwestern pine beetle: Egg galleries. (Author's illustration.)

FIRST GENERATION.

The overwintered broods of adults begin to deposit eggs about the first of June and continue doing so until August, or later, but the principal period of attack is during June and July. The larvæ begin to hatch early in June, and begin to transform to pupæ and adults early in July, the principal transformations being in July. The broods of adults begin to emerge about the middle of July, the principal period of emergence being in the latter part of July, but they

continue to come out until September, or later. Mr. Webb's observations on the development of the broods from the time eggs were deposited on June 4 and June 9 to the beginning of emergence on July 22 and July 29, show a period from deposition of eggs to emergence of adults of about fifty days.

The principal period of flight of the adults of this generation appears to be during the latter part of July and first of August, but it is evident that while some of the more retarded broods may hibernate as matured adults and larvæ, nearly all develop and emerge before activity ceases in the fall.

SECOND GENERATION.

The records of observations indicate that the earlier emerged adults of the first generation attack the trees and begin to deposit eggs about the first of August, the principal attack being in August and September.

The larvæ begin to hatch early in August and begin transforming to pupæ about the 1st of September, but no adults of this generation have been observed during the first season. The winter is passed in all stages of larvæ, with some of the parent adults. Therefore, there is one complete seasonal generation and a partial development of a second, or two complete generations annually. The principal differences in the seasonal history and generations of species 1 and 2 are the earlier beginning and ending of the first period of attack by the overwintered broods of No. 2, and the more complete development of the second generation. The habits of the two species are quite similar, except that the present species is usually associated with one or more others—Nos. 3, 5, 8, and 10.

ECONOMIC FEATURES AND METHODS OF CONTROL.

The economic features and methods of control relating to this species are quite similar to those of the western pine beetle. In case it should become isolated from the other species of Dendroctonus with which it is usually associated and become independently destructive, and if summer barking of the infested trees should be found desirable, the work should begin (under average conditions) about the middle of June and end at the middle of July, or just a month earlier than for the western pine beetle. The same rule applies for trap-trees for the first generation, which should be prepared in May and barked by the middle of July. The fall and winter work of barking trees may begin a little later, but should be completed by the 1st of May. In the more southern range of this barkbeetle the beginning and completion of such control work should be two months earlier than at the same altitude in its more northern range. (See "Methods of control" under western pine beetle, pp. 46–48.)

BASIS OF INFORMATION.

Information on this species is based on investigations by the writer at Williams, Ariz., September, 1902, at Vermejo, N. Mex., May, 1903, and near Flagstaff, Ariz., May, 1905; by Mr. J. L. Webb at Flagstaff, Williams, and Dead Mans Flat and near the Grand Canyon, Ariz., May to September, 1904, in the Lincoln National Forest at Cloudcroft, and in the Capitan Mountains, New Mexico, and in the Santa Catalina National Forest, Arizona, May to September, 1907, by Mr. W. F. Fiske at Meeks, Capitan, and Cloudcroft, N. Mex., and in the Davis Mountains, Texas, in 1907; by Mr. H. E. Burke at Panguitch Lake, Utah, in 1907; by Mr. W. D. Edmonston at Monte Vista, Colo., in 1907. Additional localities through correspondence are Show Low, Chiricahua Mountains, Arizona; San Bernardino, Cal.; Fort Garland,

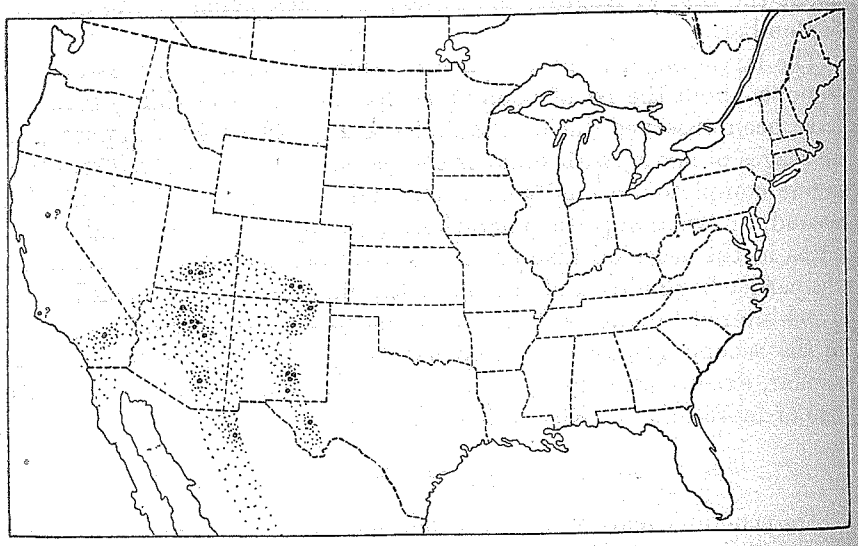

FIG. 14.—The southwestern pine beetle: Distribution map. (Author's illustration.)

Colo.; Escalante, Utah, and Santa Fe, N. Mex. The species is represented in the forest-insect collection of the Bureau of Entomology by more than 300 specimens of the insect and its work.

This species is closely related to the western pine beetle, but is distinguished by the slightly more slender form, coarser rugosities, and distinctly impressed striæ of the elytra. It is easily distinguished from the other species occupying the same range by the denser rugosities and absence of long hairs on the elytra.

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No. 3. THE ROUNDHEADED PINE BEETLE.

(*Dendroctonus convexifrons* Hopk. Figs. 15–17.)

The roundheaded pine beetle is a somewhat elongate cylindrical, reddish-brown to black, rather shining barkbeetle, 4 to 6 mm. in length, with the front of the head convex, and without frontal groove, the prothorax broad, only slightly narrowed toward the head, and finely punctured, the elytra with coarse rugosities toward the base, and the declivity with fine punctures and long erect hairs. (See fig. 15.) It attacks injured, felled, and healthy western yellow pine from southern Arizona to northern New Mexico and southern Colorado. It excavates long, slightly winding, longitudinal, and sometimes transverse and branched egg galleries (fig. 16) extending through the inner living and dying bark and grooving the surface of the wood. At intervals along the sides of the galleries single eggs are deposited. The short, cylindrical, grublike larvæ extend their larval mines at right angles to the egg galleries, usually through the inner layers of bark, and mark the surface of the wood. The transformation to pupæ and adults is sometimes in the inner bark, but probably more often in the outer bark. This barkbeetle is nearly always associated with one or more of four other species of Dendroctonus—Nos. 2, 3, 5, 8, and 10. The presence of this species is indicated by pitch tubes on the trunk and by the fading and reddish foliage.

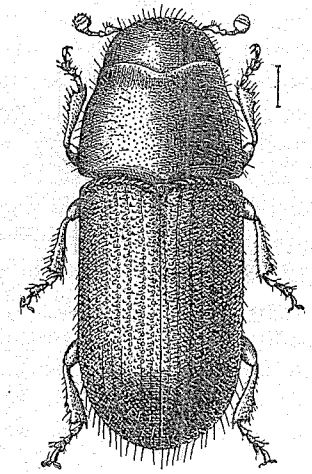

FIG. 15.—The roundheaded pine beetle (*Dendroctonus convexifrons*): Adult. Greatly enlarged. (Author's illustration.)

SEASONAL HISTORY.

OVERWINTERING STAGES.

The winter is passed in the bark of trees attacked the preceding summer, as parent adults, young to matured larvæ, young adults, and possibly pupæ, the parent adults in the egg galleries, and the broods in the outer and inner bark.

ACTIVITY OF OVERWINTERED BROODS.

The overwintered parent adults extend the old galleries or excavate new ones from the time activity begins in May until the last of June, or later. The overwintered broods of young adults begin to emerge, probably, in June, and continue to come out until September. The overwintered larvæ begin to transform to pupæ and adults in June and apparently continue to develop and transform to adults until activity ceases in the fall. Some of the adults which have transformed

from overwintered larvæ may emerge during the period from August to October, but apparently the majority go over the second winter, together with a few larvæ. Full-grown larvæ observed by Mr. Webb on June 28 had not all transformed to adults on October 10, and only a few adults had emerged. The broods developing from the eggs deposited by the overwintered parent adults may develop to adults

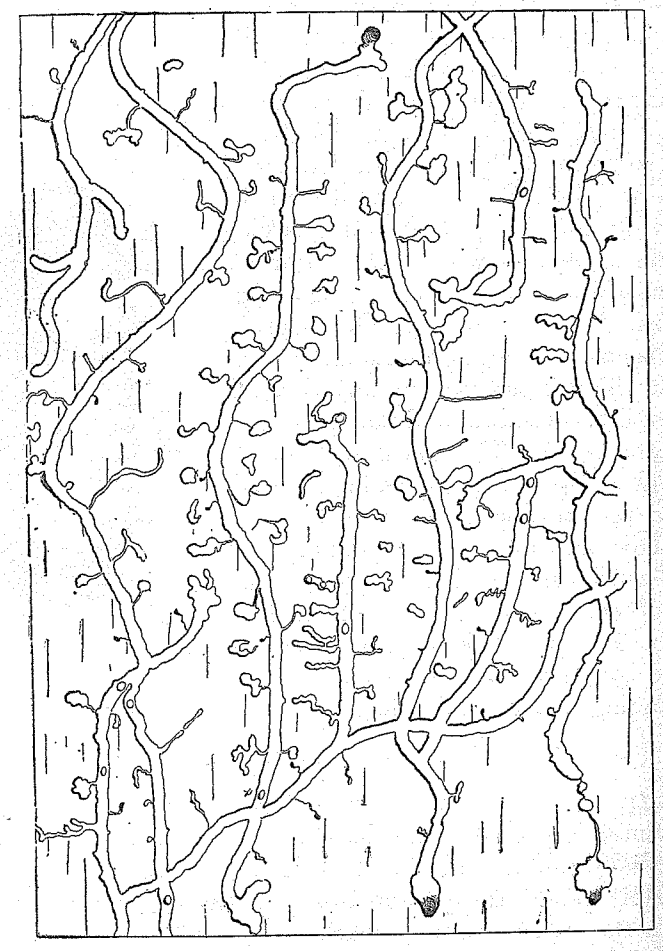

FIG. 16.—The roundheaded pine beetle: Egg galleries and larval mines. Reduced. (Author's illustration.)

before activity ceases in the fall, but the majority evidently pass the winter as medium to matured larvæ.

GENERATION.

The overwintered broods of young adults begin to emerge and deposit eggs in June and continue to do so until September, or later. Some of the larvæ from these eggs may transform to pupæ

and adults before cold weather, but evidently no adults emerge before winter.

It is very evident that there is only one partial generation annually, and that some individuals may not complete their development until the second year. It is evident, also, that the most retarded adults of the first generation may live over and deposit eggs the third year.

HABITS.

So far as known, this species confines its attacks to the western yellow pine, but it is probable that it will attack other species of pine growing within its range. It is nearly always associated with the other species of Dendroctonus and other barkbeetles in injured, dying, and felled trees. The adults enter the living to dying bark on the main trunk of the trees and excavate long, slightly winding, longitudinal, oblique, or nearly transverse and sometimes branched galleries through the inner bark, and often groove the outer layer of wood. In contrast with other species of Dendroctonus which are usually associated with it, except the Black Hills beetle, the larval mines are usually, but not always, exposed in the inner bark, and often mark the surface of the wood. Some of the larvæ may transform to adults in the inner bark, but as a rule they enter the outer corky bark for this purpose. The young adults remain there until time for them to emerge and fly. Nothing is known of the food and flight habits, and many other facts are obscure, owing to the confusion of this with other species before it was recognized as distinct.

ECONOMIC FEATURES.

The fact that this species is usually associated with one or more of species 2, 3, 5, 8, and 10 renders its specific relation to the death of trees doubtful. It is evident, however, that if it should become isolated from the other species and occur in large numbers, it would be fully capable of killing trees on its own account. During the past year it was found associated with the Black Hills beetle in the destruction of a large amount of timber, with evidence that some of the trees were killed by it alone.

METHODS OF CONTROL.

Whenever it is found that this species is causing the death of timber or is associated with other species in doing so, the bark should be removed from the main trunk of the infested trees and burned. The work should be done between the first of October and the middle of the following June. (See also "General methods of control," pp. 29–35.)

BASIS OF INFORMATION.

The preceding information relating to this barkbeetle is based on investigations by the writer at Williams, Ariz., September, 1902, at Vermejo, N. Mex., May, 1903, at Flagstaff, Ariz., May, 1904, and near Ft. Garland, Colo., June, 1906; by Mr. J. L. Webb at Flagstaff, Ariz., May to September, 1904, at Cloudcroft, N. Mex., and in the Santa Catalina National Forest, Arizona, May to September, 1907; by Mr. W. F. Fiske, at Meeks, Cloudcroft, and Capitan, N. Mex., in 1907; by Mr. H. E. Burke, at Panguitch, Utah, in 1907; by Mr. W. D. Edmonston, at Monte Vista and Laveta, Colo., and La Sal, Utah, in 1907. Additional localities through correspondence are Las Animas County, Colo.; Show Low, and Paradise, Ariz., and

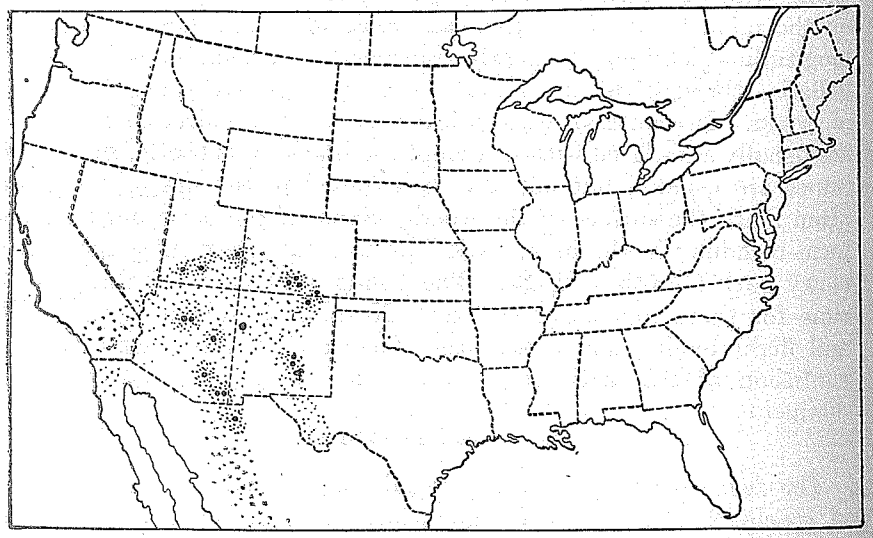

FIG. 17.—The roundheaded pine beetle: Distribution map. (Author's illustration.)

the Fort Wingate Military Reservation, New Mexico. The species is represented in the forest-insect collection of the Bureau of Entomology by more than 100 specimens of the insect and of its work.

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No. 4. THE SOUTHERN PINE BEETLE.

(*Dendroctonus frontalis* Zimm. Figs. 18–31.)

The southern pine beetle is a slender, cylindrical, brownish to black beetle, 2.2 to 4.2 mm. in length; the head is broad, with median elevations each side of a distinct frontal groove; the prothorax is punctured and but slightly narrowed toward the head; the elytra have moderately coarse rugosities between indistinct rows of punctures, and the declivity is convex, with a few long hairs. (See fig. 18.) It attacks healthy, injured, and felled trees of all of the pines and spruces, from southern Pennsylvania southward into Florida and westward into eastern Texas and Arkansas. It excavates long, winding egg galleries (fig. 19) through the inner bark, and marks, but does not groove, the surface of the wood (fig. 24). The whitish, legless larvæ excavate short, broad larval mines at more or less regular intervals at right angles along the sides of the egg galleries, usually, but not always, exposed in the inner bark. The transformation to pupæ and adults takes place in the outer corky bark. The presence of this species is indicated by pitch tubes on the main trunk of living trees, and by the fading and yellowish to red foliage as the trees die from its attack. It is a very destructive enemy of southern and southeastern pines.

SEASONAL HISTORY.

NORTHERN SECTION.

OVERWINTERING STAGES.

The broods pass the winter in the outer bark of trees attacked during the preceding summer and fall, as parent adults, matured larvæ, and possibly pupæ, and as small larvæ in the inner bark, but principally as matured larvæ in the outer bark.

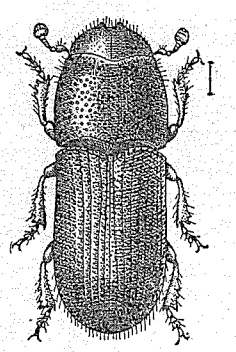

FIG. 18.—The southern pine beetle (*Dendroctonus frontalis*): Adult. Greatly enlarged. (Author's illustration.)

ACTIVITY OF OVERWINTERED BROODS.

North of South Carolina the overwintered parent adults begin to extend their galleries or excavate new ones as soon as warm weather permits in the spring (March to May) and continue their activities probably until toward the middle of May or later. The overwintered broods of young adults begin to emerge about the first of May. The first swarming period occurs about the middle of May, but stragglers continue to come out probably as late as the middle of June or July. This relates especially to its northern range and to the higher altitudes. The overwintered broods of matured larvæ begin to transform to pupæ and adults in March and April, but the principal transformation is in April, so that the adults are ready to emerge with the overwintered broods of young adults. Some of the broods of overwintered young larvæ probably develop in time to emerge with the swarm, but some of them are generally retarded and do not complete their development until in July, or possibly as late as August. It is evident that the majority of the overwintered broods are out by

the middle of June and that all are out by the last of July. Broods from eggs deposited by overwintered parent adults probably develop and emerge by the first or middle of June.

FIRST GENERATION.

The overwintered young adults deposit their first eggs early in May, and the excavating of galleries and oviposition continue probably into June, especially if the parent adults leave the completed galleries to excavate others, which they evidently do, though the general and principal attack by the overwintered broods is from the

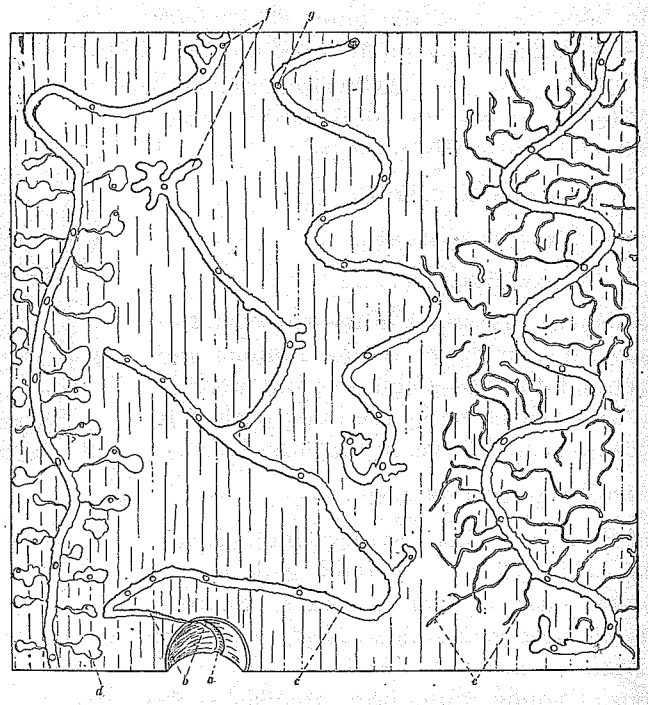

FIG. 19.—The southern pine beetle. Egg galleries and larval mines: *a*, Entrance; *b*, entrance burrow; *c*, egg gallery; *d*, normal larval mine; *e*, abnormal larval mine; *f*, terminal; *g*, ventilating burrows. Slightly reduced. (Author's illustration.)

middle to the last of May. The larvæ begin to hatch early in May and continue their active development during June, the more retarded individuals continuing active into August. They begin to transform to pupæ and adults about the middle of June, and continue until the retarded individuals are all transformed, in August or later. The developed broods begin to emerge toward the last of June and continue to come out during July or until all of the retarded broods and individuals are out in August and September or later; but practically all of the normally developed broods of the first generation are out by the last of July.

SECOND GENERATION.

The first eggs of the second generation are deposited by adults of the first generation during the first week of July. The principal attack, however, is during the latter part of July and first of August. The larvæ of this generation begin to hatch about the middle of July, continue to hatch during the latter part of July and early part of August, begin transforming to pupæ and adults during the first half of August, and continue to do so into September or later. The broods of adults begin to emerge about the 10th of August and continue to come out during the middle to last of the month, and until the last of the retarded broods have left the trees, in September or later; but practically all of the normally developed broods are evidently out by the middle of September.

THIRD GENERATION.

The adults of the second generation evidently begin to attack the trees and deposit eggs for the third generation about the middle of August, and continue to do so into September or later, though the principal attack is during the last half of August. The larvæ begin to hatch in a few days after the eggs are deposited, and develop principally during the last of August and first half of September, but some of them do not complete their development before hibernation begins in the fall. The matured larvæ transform to pupæ and adults principally during September, but continue their transformations into November or later. The developed broods begin to emerge about the middle of September, and probably continue to come out until November or later. The majority, however, evidently emerge before the middle of October.

FOURTH GENERATION.

The adults of the third generation evidently begin to attack the trees and deposit eggs about the middle of September, and continue to do so during the latter part of September and first of October, until cold weather. The principal development of the larvæ is during October, practically all becoming full grown before hibernation begins, so that the majority pass the winter as full-grown larvæ in the outer bark. Some of the earliest broods evidently begin transforming to pupæ and adults toward the middle of October, and some of them may emerge in October and November, but evidently by far the larger number of both the young adults and the developed larvæ pass the winter in the outer bark.

FIFTH GENERATION.

There may be a partial or beginning of a fifth generation, especially at the lower elevations and more southern localities of the northern section, the individuals of which pass the winter as parent adults and young larvæ.

It is evident that in the northern section of the range of this species there are from two to three complete seasonal generations during the period from about the first of May until activity ceases in the fall, or at any rate all of the broods of at least two generations develop and emerge during the period of activity within the range including the higher elevations of North Carolina and lower elevations at the northern limit, and that all of the broods of at least three generations develop and emerge at the medium and lower elevations south of Virginia, represented by a central locality included in a range of, say, 1,000 feet above and 500 feet below Tryon, N. C., while portions of the fourth and all of the fifth generation overwinter.

PERIODS OF DESTRUCTIVE ATTACK.

In the area including the mountains of North Carolina and northward there is one principal period of destructive attack, viz, during August and September, and in the area represented by Tryon, N. C., there are two principal periods of destructive attack, one from the middle of July to the last of August, the other during September and October.

SOUTHERN SECTION.

In the southern section, including the Atlantic or Gulf region of loblolly and longleaf pines, there is a complex overlapping of probably five or six generations, most difficult to define on account of the almost continuous activity during the year, but of course more or less retarded during the colder weather of the winter months. It would appear, however, that the principal periods of destructive attack are similar to those of the Tryon section.

HABITS.

The adult beetles enter the living bark, usually on the upper portion of the main trunk of standing healthy or injured trees or on the entire trunk of newly felled ones, and excavate long, sublongitudinal, winding egg galleries (figs. 19–22) through the inner bark. Eggs are placed in little niches along the sides of these galleries at more or less regular intervals of one-half inch or more.

The freshly hatched larvæ, which are short, stout, whitish grubs with a faint frontal elevation in the middle of the head and with the opposite end of the body blunt or truncate, excavate their larval mines at right angles to the egg gallery (fig. 19), and usually exposed

in the inner bark. The normal larval mine is first short and thread-like, then suddenly enlarges into a broad cavity, but sometimes, when the bark dies too rapidly or is otherwise unfavorable, a thread-like abnormal larval mine is extended for a much greater distance. When the larvæ are fully matured they bore out into the corky outer bark and excavate individual cells (fig. 22) in which those of the summer brood transform to pupæ and adults and those of the fall broods pass the winter before going through their transformations the following spring. After the adults are fully matured and when

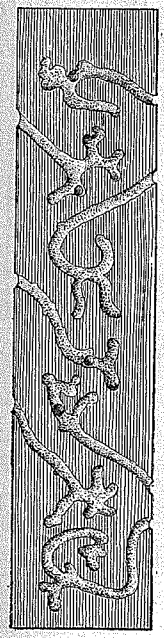

FIG. 20.—The southern pine beetle: Termination of egg galleries. (Author's illustration.)

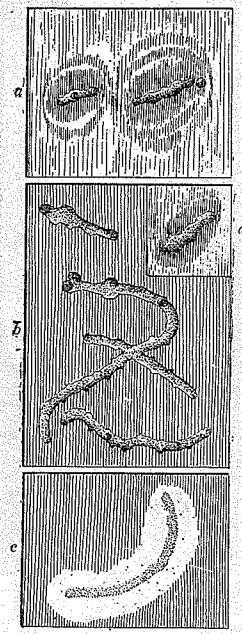

FIG. 21.—The southern pine beetle. Beginning of egg galleries: *a*, In living bark; *b*, in dying bark; *c*, marked on surface of wood (white area represents normal appearance of wood preserved by resin.) (Author's illustration.)

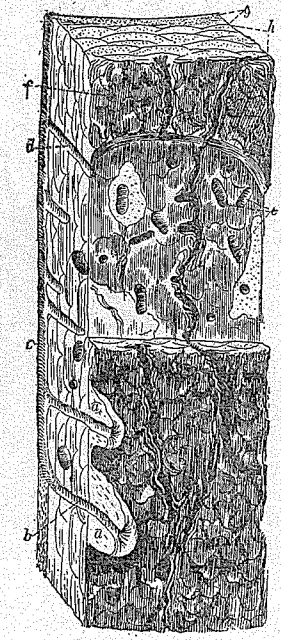

FIG. 22.—The southern pine beetle. Bark showing: *a*, Pitch tubes; *b*, entrance burrow; *c*, egg gallery; *d*, ventilating burrow; *e*, pupal cells; *f*, exit burrows; *g*, inner bark; *h*, outer bark. (Author's illustration.)

the proper time comes for them to emerge, they bore out through the bark and fly away.

The flight or swarming of this species evidently occurs late in the evening and at night, and consequently very few observations have been made on the flight habits. The finding of the beetles in electric-light globes and otherwise attracted to light is conclusive evidence that the beetles fly at night, and the fact that groups of trees are simultaneously attacked by great numbers of the beetles indicates a swarming habit. An especially interesting feature in the congre-

gating habit of the beetles was observed by Mr. W. F. Fiske, who found great numbers congregated under the loose flakes of bark of healthy trees just before their simultaneous entrance into the living inner bark. Another peculiar habit of the beetles is that of migrating from one locality or group of trees where the broods developed to another locality or group of trees some distance away, instead of continuing their attack on the trees immediately surrounding those

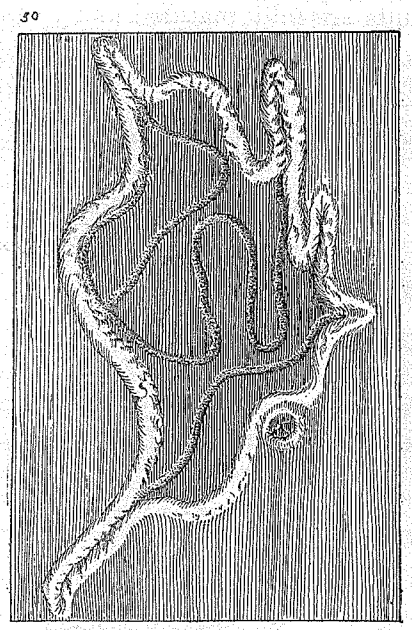

FIG. 23.—The southern pine beetle: Old egg galleries in living tree, with surrounding callus of new wood. (Author's illustration.)

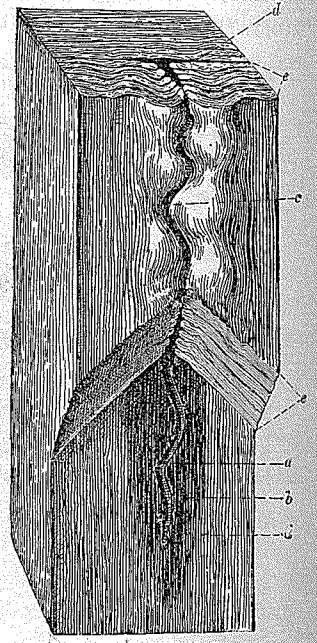

FIG. 24.—The southern pine beetle. Egg gallery in living tree marked on surface of wood six years before block was cut from tree: *a*, Mark of gallery on original surface; *b*, resinous wood; *c*, surface scar six years later; *d*, original surface or 7-year-old annual layer of wood; *e*, six subsequent annual layers of wood formed over original wound. (Author's illustration.)

from which they emerge. Apparently there are rare exceptions to this rule.

While this species will breed in injured and felled trees, it shows a decided preference for those living and healthy, whenever it occurs in sufficient numbers to attack and kill them. Its broods of larvæ must have living, or at least partially living, bark in which to complete their rapid normal development. It attacks the bark on the middle or upper trunk of medium to large pine and spruce trees, and usually selects the largest and best trees first. After the larger trees are killed the middle to lower trunk of the smaller trees may be attacked. The habit of attack and methods of excavating galleries are similar to those of the smaller western and Mexican species, all of which extend their galleries from the entrance in a transverse or sublongitudinal and tortuous course through the inner bark (fig. 19). Those of different pairs of beetles frequently cross each other so that the many primary galleries, independent of the larval mines, serve to completely girdle the tree and kill the bark. Thus these winding galleries cause a much more rapid death of the bark and foliage than do the straight longitudinal galleries, like those of the spruce beetles and the Black Hills beetle. The trees are killed by the girdling effect of the winding primary galleries in the bark of the middle portion of the trunk, which, it has been demonstrated, is the most vital part, or at least has less power of resisting injuries than the lower portion and base. Instead of the leaves of the trees remaining green until the next season, as they do on trees infested by the spruce beetle and the Black Hills beetle, all except those on the trees attacked late in the season commence to fade in a few weeks after the trees become infested.

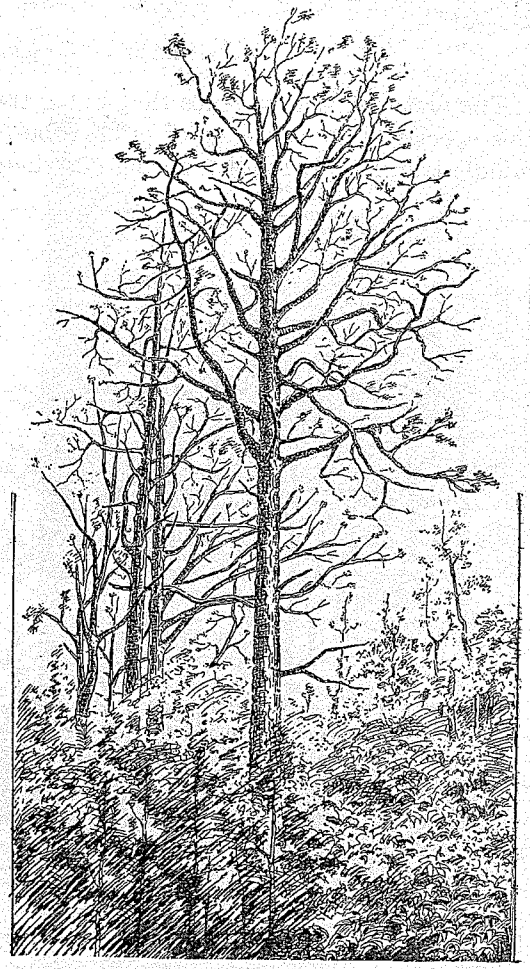

FIG. 25.—White pine timber killed by southern pine beetle Condition in October, 1894, of trees which died in 1891 and 1893. (Original, from photograph.)

ECONOMIC FEATURES.

This species may be considered as one of the most dangerous enemies of the pine forests of the Southern States. It devastated the pine forests over large areas in West Virginia and Virginia in 1891 and 1892, and the extensive dying of pine timber in the Southern States during

the past century, to which there are numerous references, was more than likely caused by it. It has been more or less active in the States south of Virginia, southward to Texas, since 1902, and in some localities and during some years it has killed a large amount of timber. It is therefore a constant menace to the pine timber of the Southern States.

EVIDENCES OF ATTACK.

The first external evidence that living trees are being attacked by this species is the presence of pitch tubes (fig. 22) on the upper to middle trunk, or of reddish boring dust lodged in the loose bark and around the base of the trees. If the attack is sufficient to kill the trees, the presence of the insect will be indicated in about two weeks by the fading and yellowish appearance of the leaves, and in about a month after the attack the leaves will be yellowish to reddish, all of the bark except that on the base of the trunks will be dead, and the broods of the destructive enemy will be ready to emerge or will have emerged. After the leaves have become reddish brown practically all of the broods will be out. Positive evidence, however, that the above-described external conditions are caused by this beetle is obtained only by authentic identification of specimens of the insect or its work taken from the affected trees. The presence of the insect in destructive and dangerous numbers is indicated by frequent patches of dying pine or spruce during July, August, and September, and the sudden death of the timber over large areas will indicate a destructive invasion requiring prompt and radical measures for its control.

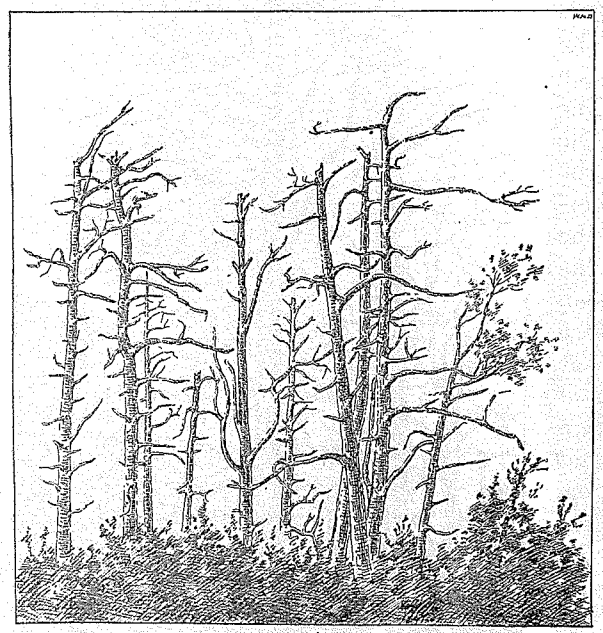

FIG. 26.—Table Mountain pine, Mineral County, W. Va., seven years after it was killed by the southern pine beetle. (Original, from photograph.)

EFFECTS ON COMMERCIAL VALUE OF THE WOOD.

The commercial value of the wood of trees killed by this beetle is reduced by the bluing of the sapwood (fig. 29), often before the leaves begin to turn yellow, though the heartwood, especially of the larger spruce and yellow pine, usually remains sound for many years after the trees die; both the sap and heart wood of the smaller trees, and even of the large pitch, loblolly, and Table Mountain pine, deteriorate rapidly (figs. 26, 27), and therefore must be utilized immediately after the trees begin to die, in order to save anything of commercial value.

Serious losses of a secondary nature, both of dead and adjoining living timber, may result from fires started in the dead timber. Therefore the prompt utilization of the beetle-infested trees and the prevention of forest fires are important to obviate total destruction of the timber.

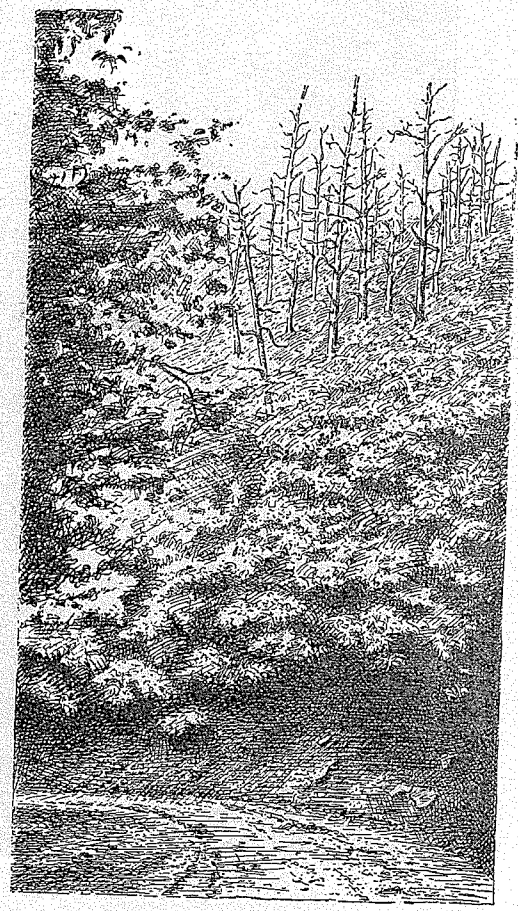

FIG. 27.—A forest of Table Mountain pine, Mineral County, W. Va., seven years after it was killed by the southern pine beetle. (Original, from photograph.)

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication and spread of the beetle are found in areas of large, matured timber and where the trees are frequently struck by lightning, felled, or injured by storms, etc., during the summer months.

The odor from the exposed wood, and perhaps from the wilting foliage of a few trees cut in the midst of a healthy growth of pine during the summer, serves to attract this species, apparently from a long distance, and to induce attack on the surrounding healthy trees. Therefore, any irregular or sporadic local cutting of timber for fuel or any limited purpose during the summer months furnishes most

favorable conditions for the concentration of individuals from widely scattered colonies and broods, and thus increases their power of attacking and killing the surrounding living trees. By this means their forces are greatly augmented, and much of the surrounding timber is killed... If conditions favorable for the continued concentration of the beetles prevail from year to year, an invasion like that of 1891 and

FIG. 28.—Spruce timber killed by the southern pine beetle, mountains of Transylvania County, N. C. (Original.)

1892 may be started, which may far exceed any forest fire in the history of the country, both in the extent of area covered and in the number of trees of commercial value killed.

Unfavorable conditions for the multiplication of the insect and its destructive attack on living timber will be found in large areas where the older matured trees have been removed and where continued timber-cutting operations are carried on under some regular system of

forest management, as also where there are regulations governing the time of year when the timber shall be cut, in both regular and irregular operations, as well as the time when lightning-struck and otherwise injured trees shall be removed or barked.

METHODS OF CONTROL.

In order effectually to destroy the insect, it is only necessary to remove the infested bark from the trunks and burn it. It is entirely unnecessary to burn or otherwise destroy any part of the wood from which the bark has been removed, because the destructive beetle does not enter the wood and rarely breeds in the bark of the tops and branches. With this particular species, however, it is necessary to burn the bark after or before it is removed, because the matured larvæ, pupæ, and adults pass the winter in the outer dry bark, where they would otherwise survive and emerge in the spring, to attack other trees.

In localities or areas of greater or less extent where it has been positively determined that the timber is attacked and killed by this beetle, the principal groups of trees which are actually infested with the broods should be located in the period from November to March, and the standing trees, including all of the larger ones, so infested should have the bark removed from the main trunks or be felled and barked, or the entire trunk scorched, burned, placed in water, or converted into lumber and the slabs burned, as in each case is more practicable or advisable. In the northern section this work should be begun not earlier than the 1st

FIG. 29.—The southern pine beetle: Section of pine trunk, bark removed, showing the galleries marked on surface of wood and the dark patches caused by the blueing fungus. (Original.)

of November and completed not later than the 1st of April, and in the southern section it should be begun in December and completed in February. If at least 75 per cent of the infested trees, including all of

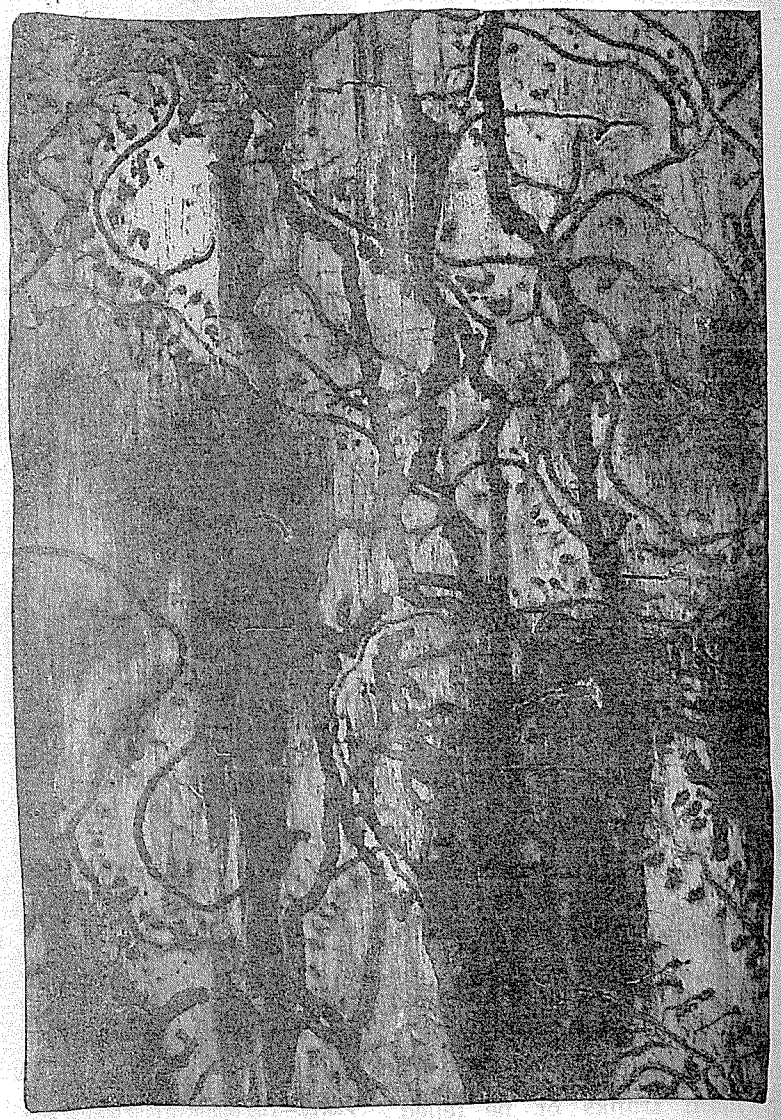

FIG. 30.—Egg galleries and larval mines of the southern pine beetle, and larval mines of roundheaded bark-borer. (Original.)

those in the larger patches, within 10 or 15 square miles are thus treated, it should destroy enough of the broods to protect the remaining timber for several years. If, then, this practice is followed up

whenever small patches of infested timber are found it should serve to keep this enemy under complete control.

Summer operations in the felling and barking of infested trees are not to be recommended except in special cases, when, for example, it is desirable under a clear-cutting system to include the healthy timber with the infested, or when practically all of the timber over a large area is infested during the spring and summer; otherwise, if only the infested trees are cut and healthy ones left, the felled and barked trees attract the flying beetles to the locality, and thus the death of a large amount of the surrounding healthy timber results.

If it is desirable to make clear cuttings during the summer, to include small or large areas of infested timber, it should be done during the principal periods of larval development—August and September in the northern section, and from July to October in the southern section.

Whenever it is desirable to protect a small or large estate, or a particularly valuable section of the forest surrounded by forested areas in which the infested timber can not or will not be cut and barked, the greatest precautions should be taken to prevent the cutting of pine timber for any purpose during the spring, summer, and early fall. The only exception would be lightning-struck or storm-broken and felled trees, which, under certain conditions, should be cut and removed, or burned with the tops, if possible, the next day after the injury occurs. If the logs are removed the tops should be burned over the stumps.

If pine cord wood is cut during the summer, it should be done under the clear-cutting system and confined to a section of the forest away from the more valuable timber which it is desirable to protect from insect attack. Cord wood, new lumber, etc., should never be piled in proximity to living pine trees, neither should building operations involving the use of new pine lumber or fresh paint be conducted during the summer in or near a desirable grove of pine or spruce. All of the above relates especially to sections *where the beetle is present in the surrounding forest.*

Some experiments conducted by Mr. W. F. Fiske, while working on forest insects, indicate that if the infested trees are felled in November and December and left flat on the ground and the upper side of the trunk is scored or blazed so as to facilitate the entrance of water from rains and melting snows, the broods will be killed by the abnormal wet condition of the inner bark.

When the infested timber is near streams or ponds the broods may be destroyed by placing the unbarked trunks or logs in the water, provided the work is done before the broods begin to emerge.

Whenever the infested timber can be utilized for lumber the burning of the bark and slabs is all that is necessary.

BASIS OF INFORMATION.

Information on this species is based on investigations by the writer for the West Virginia Agricultural Experiment Station in many localities in West Virginia, July, 1891, to December, 1896; for the United States Department of Agriculture at Fletchers, N. C., July and November, 1902; at Tryon, N. C., July, 1902, March, 1903, and July, 1904; at Boardman, N. C., Inman, N. C., and Kirbyville, Tex.,

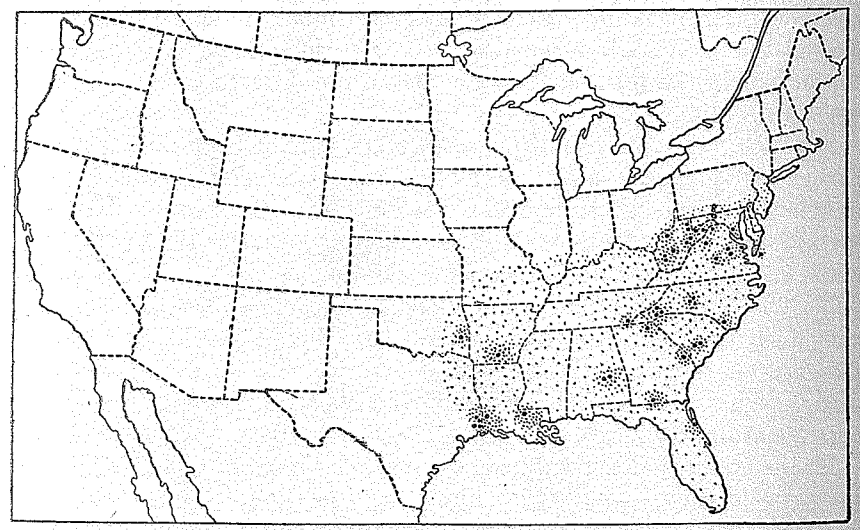

FIG. 31.—The southern pine beetle: Distribution map. (Author's illustration.)

November, 1902; at Pink Beds and Pisgah Ridge, N. C., July, 1904; at Virginia Beach, Va., November and December, 1907, and April, May, and June, 1908; by W. F. Fiske at Tryon, N. C., March to September and December, 1903, April to December, 1904, March to December, 1905, and May, June, and July, 1906; at Clyo, Ga., August, 1903; at Pisgah Ridge, N. C., September, 1903, and September, 1904; at Cornelia, Ga., November, 1903; at Chicora, S. C., November, 1904; at Call, Tex., February and November, 1905; at Beaumont and Deweyville, Tex., Thomasville, Ga., Montgomery, Ala., Wilson and Singer, La., and Pink Beds, N. C., March, 1905; at Ducktown and Wetmore, Tenn., Ellijay, Ga., October, 1905, and Green Bay, Va., June, 1906. Additional localities through correspondence and from other collections are Calhoun, Ala.; Green Bay, Cobbs Island, Glen Allen, and Auburn Mills, Va.; Hampton, Ark.; Demorest, Ga.; Indian Territory, and Haw Creek, Fla. The species is represented in the forest-insect col-

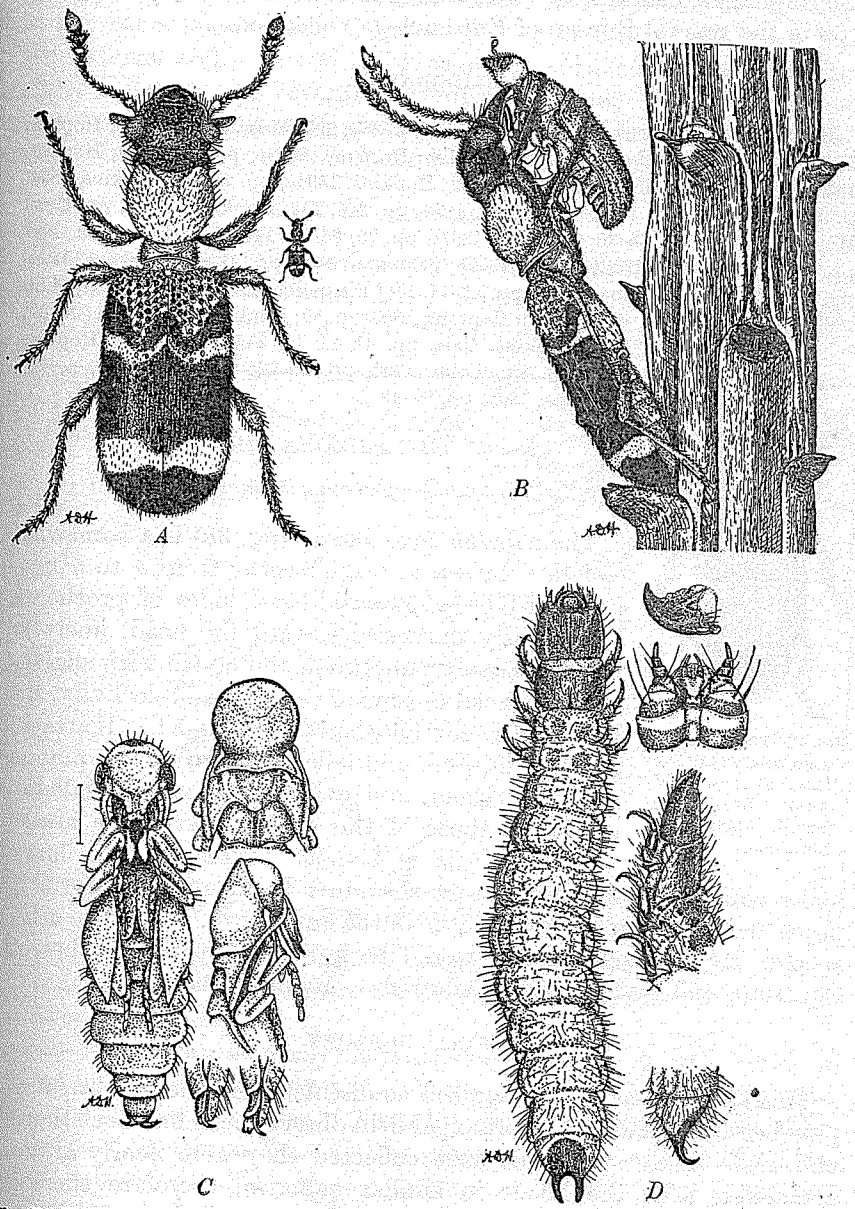

FIG. 32.—The European barkbeetle-destroyer (*Clerus formicarius*), introduced from Europe in 1892–1893:[a] *A*, Adult, dorsal aspect, natural size at right; *B*, adult, showing attitude when feeding on barkbeetle; *C*, pupa and details; *D*, larva and details. Greatly enlarged. (Author's illustration.)

[a] Hopkins, 1899*a*, pp. 297–231.

lection of the Bureau of Entomology by 65 specimens in the West Virginia Agricultural Experiment Station collection and by more than 150 in the general Bureau of Entomology collection.

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Hopkins, 1892*a*, pp. 64–65; Hopkins, 1892*b*, p. 353; Schaufuss, 1892, p. 316; Hopkins, 1893*a*, pp. 187–189; Hopkins, 1893*b*, p. 143; Hopkins, 1893*c*, pp. 186, 213; Hopkins, 1893*d*, pp. 123–129; Hopkins, 1894, p. 292; Hopkins, 1894*a*, pp. 71–76; Hopkins, 1894*c*, p. 348; Lintner, 1895, p. 500; Hopkins, 1896, pp. 246, 250; Hopkins, 1897*a*, pp. 29–41; Hopkins, 1897*b*, pp. 35–36; Hopkins, 1897*c*, pp. 79, 94–95, 147–151; Chittenden, 1897, pp. 67–75; Hopkins, 1898*b*, pp. 104–105; Schwarz, 1898, pp. 81–82; Hopkins, 1899*a*, pp. 394–414, 448; Hopkins, 1899*b*, pp. 11, 13, 14; Chittenden, 1899, pp. 55–56; Hopkins, 1902*b*, p. 21; Hopkins, 1902*c*, p. 20; Hopkins, 1903*a*, p. 59; Hopkins, 1903*b*, pp. 270–275, 281; Hopkins, 1904, pp. 41, 42, 44; Felt, 1905, p. 6; Hopkins, 1906*c*, p. 80; Webb, 1906, pp. 20–22; Hopkins, 1907, p. 163; Hopkins, 1909, pp. 90–95.

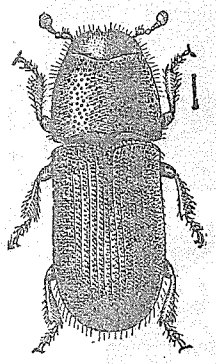

FIG. 33.—The Arizona pine beetle (*Dendroctonus arizonicus*): Adult. Greatly enlarged. (Author's illustration.)

No. 5. THE ARIZONA PINE BEETLE.

(*Dendroctonus arizonicus* Hopk. Figs. 33, 34.)

The Arizona pine beetle (fig. 33) is a somewhat elongate, brown to black beetle, from 4 to 5 mm. long, with broad grooved head, sides of prothorax but slightly narrowed toward the head, finely to rather coarsely punctured, and elytra with slightly coarse rugosities toward the base and declivity, the latter with a few long hairs. (See fig. 34.) It attacks healthy, injured, and felled western yellow pine in central Arizona, and evidently excavates galleries similar to those of the southwestern pine beetle, with which it is usually confused. The larvæ make concealed food burrows in the inner bark, and transform to pupæ and adults in individual cells in the outer bark. Like the other species, its destructive work would be indicated by pitch tubes on the trunk and by the fading yellowish to reddish foliage.

SEASONAL HISTORY.

This species was not recognized as distinct from the southwestern pine beetle until after the principal field observations had been made, and while many specimens were collected they were nearly always associated with the latter in similar galleries; therefore there is somewhat meager evidence on which to base conclusions relating to seasonal history, habits, etc. Apparently, however, its habits are in most respects similar to those of the southwestern pine beetle,

although it is distinctly separated by specific characters. It is more nearly related to the southern and smaller Mexican pine beetles than to any other species, and therefore it may be found that it has two generations, and a partial third, annually. It is also probable that under isolation and favorable conditions it may, like the southern pine beetle, become very destructive. (See "Economic features" and "Methods of control" under Nos. 1, 2, and 4.)

BASIS OF INFORMATION.

Data regarding this species were obtained through investigations by the writer at Williams, Ariz., September, 1902, and Flagstaff, Ariz., May, 1904, and by J. L. Webb at Flagstaff and Williams, Ariz.,

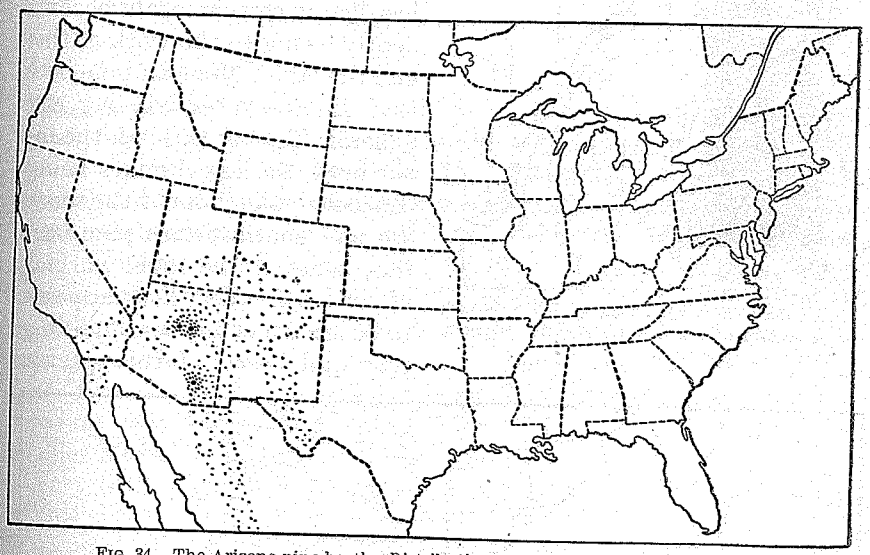

FIG. 34.—The Arizona pine beetle: Distribution map. (Author's illustration.)

May to September, 1904, and Flagstaff, Ariz., August, 1907. It is represented in the forest-insect collection of the Bureau of Entomology by over 50 specimens.

This species can be easily distinguished from No. 2, with which it agrees in size, by the long hairs on the declivity of the elytra, and from the smaller examples of No. 8 by the fine punctures of the striæ of the declivity, from No. 3 by the grooved head, and from No. 6, to which it is closely allied, by the distinctly more pubescent pronotum and elytra.

BIBLIOGRAPHY.

Hopkins, 1909, pp. 95–97.

No. 6. THE SMALLER MEXICAN PINE BEETLE.

(*Dendroctonus mexicanus* Hopk. Figs. 35, 36.)

The smaller Mexican pine beetle (fig. 35) is a dark brown, elongate, cylindrical barkbeetle, ranging in length from 3 to 4 mm., with head broad and grooved, prothorax but slightly narrowed toward the head, and punctured, and elytra with coarse rugosities toward the base and declivity, the latter with long hairs. It attacks pine trees in Mexico, where a large amount of timber has died in certain localities, evidently owing to the work of this and the larger Mexican pine beetle. It excavates winding egg galleries (fig. 35) through the inner bark, the larval mines being concealed, like those of the western and southwestern pine beetles, beneath the inner surface of the bark. Very little appears to be known of the seasonal history and habits of this species,

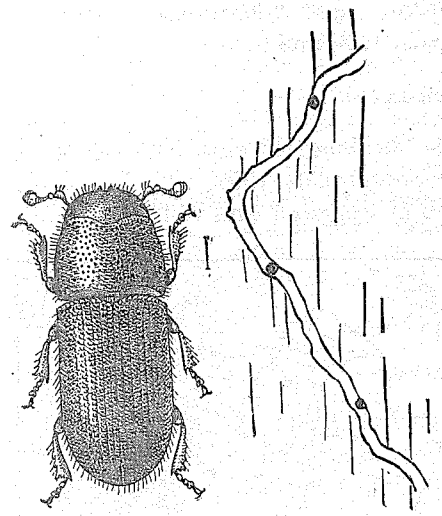

FIG. 35.—The smaller Mexican pine beetle (*Dendroctonus mexicanus*): Adult, greatly enlarged, and section of egg gallery, slightly enlarged. (Author's illustrations.)

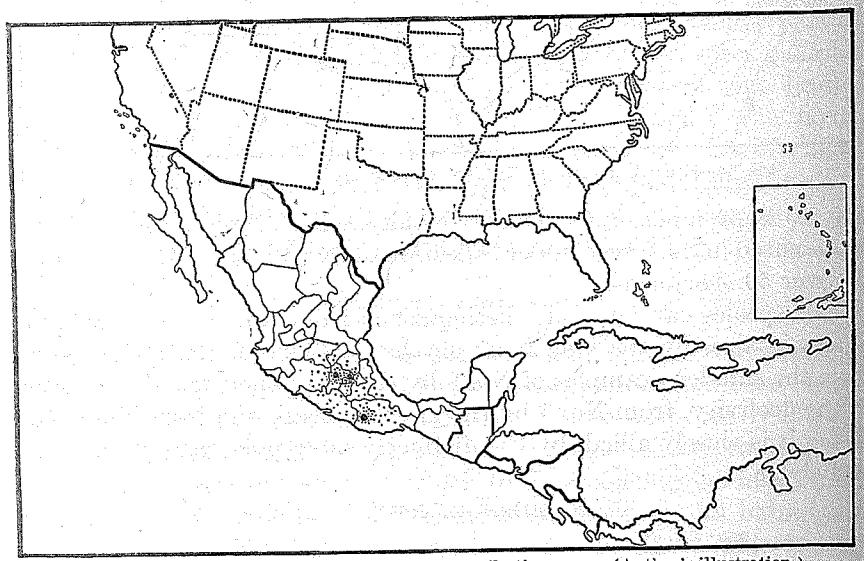

FIG. 36.—The smaller Mexican pine beetle: Distribution map. (Author's illustration.)

but evidently they will be quite similar to those of the southwestern, southern, and Arizona pine beetles. It will therefore be subject to the same general treatment for its control, namely, the removal and

burning of the infested bark during the principal period of larval development and during the inactive or overwintering periods, if such are found within its range.

This species has not been recognized within the United States, but it is not improbable that it may be found in the pine forests of southern Arizona and New Mexico.

The writer has identified thirty-six specimens received from Prof. A. L. Herrera and Dr. S. J. Bonansea, collected from pine in Amecameca, Michoacan, and Tacubaya, Mexico.

BIBLIOGRAPHY.

Hopkins, 1906*c*, p. 80; Hopkins, 1909, pp. 97–99.

No. 7. THE LARGER MEXICAN PINE BEETLE.

(*Dendroctonus parallelocollis* Chap. Figs. 37–39.)

The larger Mexican pine beetle is a somewhat elongate, cylindrical, dark brown to black barkbeetle, 5 to 6 mm. in length, with broad, deeply grooved head; broad prothorax, with sides nearly parallel and but slightly narrowed toward the head, and elytra with dense, moderately coarse rugosities, the declivity with coarse punctures and long erect hairs. (See fig. 37.) It attacks living pine trees in Mexico, excavating coarse, slightly winding, longitudinal or oblique and sometimes branched egg galleries (fig. 38) through the inner bark. The larval mines are evidently concealed beneath the inner layers of bark, and the larvæ evidently transform to pupæ in separate cells in the outer bark. It is usually associated with the smaller Mexican pine beetle in the same tree.

Very little appears to be known in regard to the seasonal history of this species, but it is so closely related to the Colorado pine beetle in general characters that it is probably quite similar in seasonal history as well as in habits and in the character of injury to the trees, except in such minor differences as may be brought about by its more southern range. It is evident that the unhealthy and dying condition of the pine in certain localities in Mexico, which has been reported from time to time, is caused largely by this species and by the smaller Mexican pine beetle.

Ten specimens of the beetle and one of the galleries, received from Prof. A. L. Herrera, collected in Michoacan, etc., have been examined and identified by the writer.

If this species is found overlapping the range of the Colorado pine beetle, it can be distinguished from that species by the slightly longer prothorax, with sides more parallel and less narrowed toward the head.

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Hopkins, 1906, pp. 80–81; Hopkins, 1909, pp. 99–101.