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NOTABLE DEPREDACTIONS BY FOREST INSECTS.

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INTRODUCTION.

In a review of the principal recorded depredations by forest insects in Europe and North America during the past four hundred years one is forcibly impressed with the idea that insects have exerted a most important influence on the history and modification of the forests, and thus indirectly on that of the countries themselves.

Among the natural destructive influences which have brought about changed conditions, storms, insects, and diseases have doubtless been primarily concerned in causing radical changes in local conditions, such as the successive disappearance of generations of matured trees, the disappearance of one or more tree species to be replaced by other species, or the total destruction of the forest cover.

The insects primarily concerned in depredations on living trees and in the killing of the timber over large areas fall, according to their food and breeding habits, into two groups. One includes those species of barkbeetles and bark-boring grubs which bore in the living bark and excavate burrows and galleries through the vital cambium, on the main stem or trunk, thus serving to girdle and kill the tree. The other includes those species which feed on the leaves and occur in such numbers as completely to defoliate the trees during two or more successive seasons, thus preventing the performance of the necessary vital functions of the foliage to such an extent as to cause the death of the trees.

DEPREDATIONS IN EUROPE.

It appears that the depredations by forest insects in the natural and planted forests of Europe during the past four hundred and fifty years which have been most notable in their character and extent have been caused by but a few species of defoliators and bark borers.

DEFOLIATING INSECTS.

"NONNE" MOTH.—The "nonne" moth (*Liparis monacha* L.) is light gray, stout-bodied, about 1 inch long, with wings spreading about 2 inches. It appears on the wing during July and August in vast swarms and deposits its eggs on the bark of the tree trunks. After the moths have completed their work of egg laying they die. The eggs remain on the trees over winter and until in April and May,

when they hatch into small, black, hairy caterpillars, which soon enter upon their mission of devastation. At first they congregate in small colonies, but later they become grayish in color and more active and scatter about, going from branch to branch and from tree to tree, feeding ravenously on the foliage and growing rapidly. This activity continues until they have attained their full growth as caterpillars. They then cease feeding and transform to the chrysalis stage in slight webs attached to the leaves, branches, or bark. About two weeks later the transformation to the moth, or adult stage, takes place and the life round, with its egg-laying and larval activity, is repeated.

The conifers, such as spruce, fir, and pine, suffer most from the ravages of this insect, but after it has completed the defoliation of the conifers, it will also attack the deciduous or broad-leaved trees and shrubs, such as beech and oak.

The history of the outbreaks of this insect is a story of repeated devastations and enormous losses of timber and expenditures of money in different sections of Germany, Austria-Hungary, Russia, Norway, and Sweden.

It appears that between the middle of the fifteenth and the beginning of the nineteenth centuries there were 17 invasions of the insect of sufficient magnitude to have been the subject of comment in European literature.

From 1794 to 1797 great invasions were reported from middle Germany to western Russia. Evidently these widespread and most alarming depredations were suddenly brought to an end by the appearance of a disease in June, 1797, which, like a great infectious pestilence, destroyed the caterpillars as rapidly as they themselves had destroyed the leaves of the trees. Bechstein, in his *Forest-Insectology* (1818), gives an account of the invasion in western Russia and its sudden termination, in which he says:

It is horrible to travel in districts where these caterpillars swarm. Many thousand crawl up and down the trees. One can not take a step without treading on a number of them. There is a perpetual rain of their excreta, which often lies 6 inches deep, and being dissolved by the rain collects in puddles, which diffuse a pestilential stench. One can form no idea of the magnitude and terrible nature of the destruction. Fortunately, nature herself stopped the pest through a kind of dysentery which attacked the caterpillars in the beginning of June, 1797. This deadly sickness was attributed to a kind of mildew. The caterpillars collected together in great thick clumps 4 to 6 inches across, the excreta became pale, the intestines dirty, and so they died, leaving behind them a disgusting stench.

It is said that in 1839 and 1840 there occurred in the forests of northern Germany the first great outbreak of the nineteenth century. A writer in 1890 refers to this and subsequent invasions as follows:

In connection with the injury caused by the "nonnen" in this century we may briefly mention here the extensive plague of 1839 and 1840 in upper

Suabia (Wurtemberg) which ravaged many hundreds of "morgens" of pine forest. The same thing was repeated in 1855, and at the present moment (1890) is appearing almost in the same spots in very serious manner. But the most considerable "nonnen" pest of all took place in Russia, and spread from 1845 to 1868 in a most devastating manner over Poland, Lithuania, and east Prussia. The invasion (of moths) in east Prussia began suddenly in 1853, in the night of July 29-30, and covered an area of about 60 German square miles in the administration of Gumbinnen, after it had already crossed over, in 1851 and 1852, the southern boundary of the administration of Königsberg. At that time the moths were driven by a storm into the sea while on their way, so that the insects were thrown by the waves upon the coasts for a distance of 10 German miles in a bank 7 feet wide and 6 inches thick, and were used as manure by the coast inhabitants. The extent of the ravages in Russia at that time was 6,400 German geographical square miles, and in east Prussia making a total of 7,000 miles. At the very least, 55,000,000 Prussian cords of wood, or 185,000,000 cubic yards of wood, became the prey of "nonnen" and bark beetles.

The next great invasion to attract general attention was in 1889-1892, which, it is said, extended over nearly all of Bavaria south of the Danube, causing a great loss and the expenditure of large sums of money in efforts to control the outbreak.

Large sums of money have been expended in various efforts toward the control of the "nonne." The methods which seem most effective are directed toward destroying the eggs on the trunks of the trees and preventing the migration of caterpillars from trees defoliated by them to adjacent uninfested trees or uninfested sections of the forest. This is accomplished by placing a band of some sticky substance, or so-called "birdlime," on the bark around the trunks of the trees. This acts as a barrier against the ascent of the caterpillars and also prevents some of them from coming down from the trees they have defoliated.

In 1892 the writer passed through a section of Bavaria in which all of the spruce trees for many miles were thus banded, and, in addition, thousands of small boxes were fastened in the trees to encourage the nesting of insectivorous birds.

In 1897-1902 there was an invasion of the "nonne" in Sweden. Information was secured by the writer through correspondence in 1903 with Mr. D. Cappelen, of Thelemarken, Norway, in regard to an outbreak of *Dendrolimus (Bombyx) pini* in Norway and the "nonne" in Sweden. The latter was first observed in the white pine. In 1898 it had spread over an area of more than 27,000 acres, and the sum of \$100,000 was expended in fighting it. It is further stated that the white pine over about 7,500 acres was totally ruined, but the silver pine, which composed about 60 per cent of the same area, was not killed.

It appears that very satisfactory results were had from liming or gluing, at a cost of about \$2 per acre. Experiments were also made

with a disease of the caterpillars, which seemed to result in spreading the infection.

Among the other defoliating insects which have habits similar to those of the "nonne" moth and which have caused notable depredations may be mentioned the pine spinner, the gipsy moth, and three species of sawflies.

PINE SPINNER (*Dendrolimus [Bombyx] pini* L.).—This is a stout-bodied, grayish-brown moth, considerably larger than the "nonne" moth. It appears on the wing in July and deposits its eggs on the trunks and branches of the trees during July and August. These hatch into caterpillars in August and feed on the foliage of the trees until cold weather, when they descend to the ground and hide in the moss and leaf cover, where they pass the winter. Early the next spring—February to April—they ascend the trees and feed on the foliage, as before, continuing to feed until June, when they make their cocoons, in which to transform to the chrysalis stage. These cocoons are attached to the twigs, branches, and trunks of the trees and underbrush, and the moths begin to emerge from them in July, to repeat the process of egg laying.

This insect, it appears, confines its attack to the pine. Its distribution extends from Lapland to Corsica and from England and France eastward to the Ural Mountains wherever there is a dense growth of pine.

It appears that one of the greatest outbreaks of this insect was in middle Germany in 1862 to 1872, over an area of 2,349 German square miles, in which the pine over some 100,000 acres was damaged and that on some 25,000 acres was eaten clean, causing an estimated damage of 2,366,000 marks (\$565,000).

According to quite full information received by the writer through correspondence with Mr. Cappelen, of Norway, there was a destructive outbreak of this insect in Norway in 1900 to 1903, causing extensive losses of timber and the expenditure of large sums of money in efforts to control it. The remedies consisted in felling the small trees and "gluing" or liming the remaining ones, in the same manner as for the "nonne" moth, the work being done during the winter to prevent the caterpillars from ascending the trees the following spring. This operation was performed over some 7,000 acres in the winter of 1903, at a cost of about \$2.65 an acre, more than 400,000 pounds of glue having been used. Evidently this treatment was quite successful in controlling the ravages of the insect, so far as the treated trees were concerned. It appears that considerable service was also rendered by the insect parasites and diseases of the caterpillars.

GIPSY MOTH (*Porthetria dispar* L.).—This is another insect somewhat similar in appearance and habits to the “nonne” moth, but larger. The presence of this insect in Massachusetts and adjoining States and its power of destruction render its history of especial interest, but since this has already been discussed in State and Government publications it is not necessary to refer to many examples of its work in Europe.

It is said that in the summers of 1854, 1855, and 1856 the zoological garden at Berlin suffered a complete defoliation, and that in 1874 and 1875 the willow hedges of the bürgermeister of Nöthlich were devastated. In 1875 and 1877 great numbers appeared on the Charlottenburg causeway and in the zoological gardens at Berlin.

In 1731 caterpillars of the gipsy moth committed terrible havoc among the cork oaks of France. In 1761 the trees in the orchards and gardens, the bushes in the fields, and the whole forests in Saxony and neighboring portions of Germany were defoliated. In 1794 there was another general outbreak of similar character. In portions of France the caterpillars were so abundant as to defoliate the forests in 1837. In 1871 the oak forests of portions of Italy were so entirely defoliated that many trees died.

FALSE CATERPILLARS.—There is a class of curious insects which resemble in general appearance and habits the caterpillars of moths, but which in reality are the larvæ of so-called sawflies belonging to the same order of insects as the common bees and wasps. Among the large number of species of this class of defoliators there are some which are exceedingly destructive. Those worthy of special mention in this connection include three species belonging to three different genera.

In 1857 one of these (*Lophyrus pini* L.) is said to have killed one-third of the older timber on 1,900 hectares of woodland in Wurttemberg and Bavaria, and between 1862 and 1896 three outbreaks of another species (*Lyda hypotrophica* Hartig) were recorded, one in 1862 in Wurttemberg, one in 1890 in Mähren, and one in 1888–1896 in Bavaria and Bohemia.

The species of special interest in this class is the larch worm, *Nematus erichsonii* Hartig of literature, which has from time to time during the last half century attracted attention in Europe and North America. The adult of this insect is about the size of the common house fly. It appears on the wing in June and July and deposits its eggs in the bark of new-growth twigs of the larch (known in this country as tamarack, hackmatack, larch, etc.). The eggs soon hatch into greenish worms or larvæ, later becoming grayish, which feed on the leaves during July and August, and often occur in such

numbers as to defoliate the trees over thousands of square miles. As soon as these larvæ attain their full development they descend to the ground, where they burrow beneath the moss and decaying leaves and enter the earth, each individual making a dense egg-like brown cocoon, in which it passes the winter as a larva. In June these overwintered larvæ transform to pupæ, and a short time afterward to the adult sawflies, which emerge from the cocoons and fly to the tops of the trees to repeat the egg-laying process. This insect is now distributed throughout north and central Europe, the British Islands, eastward into Siberia, and in eastern North America^a from central Michigan to Labrador.

The earliest records of depredations by this insect relate to an outbreak in Denmark in 1827-1829, followed by another in 1839-1847, and an outbreak in 1835-1838 in Holstein. In 1880 it was said to be abundant in Siberia, and in 1892 abundant and injurious in Sweden. In 1894 its first occurrence in Norway was reported. In 1903 it was reported as injurious to the larch in Finland, and in 1906 its depredations in Cumberland, England, were the subject of a special paper by Theobald and one by MacDougall. It is said that the most injurious and most prolonged attack of this insect took place in Denmark from 1839 to 1847. According to Boas:

It appeared here in enormous numbers over some larch cultures covering some 360 acres. The larvæ were first noticed in 1839 on a small number of larches, but in 1840 the insect had already spread so much that half the larches were defoliated, and in 1841 matters were still worse, hardly a tree being spared, except the youngest. In 1842 and 1843 the damage was about the same as in 1841. Drought and cold probably kept the insect back in 1844. In 1845 the attack was about as in the previous year (1843?) and in 1846 it was worse than ever before. The trees, after several years' repeated defoliation, began to die, and it was noticed that the older trees were more sensitive than young ones. In 1847 the insect became still more destructive and attacked even the very smallest larches, which had hitherto escaped. In 1848, however, it completely disappeared almost in a twinkling, and there began to be hope that the forest would finally recover, in spite of the damage it had received, but, so far as can be learned from the meager information of later years, the larch forests had received an irremediable blow—the health of the trees had suffered too much.

BARK-BORING INSECTS.

Among the notable depredations by bark-boring insects on the forest trees of Europe those caused by the true barkbeetles hold first rank. Only a few species, however, appear to be primarily involved in the destruction, although there is a very large number of species which infest both the conifers and the broad-leaved trees after they have been injured or become unhealthy from some other cause.

^a See p. 158.

There are two or three species which are capable of killing spruce and pine, one or two destructive to the oak, and another is said to kill the elms.

There has been much dispute among European writers as to whether any of these barkbeetles really attack healthy trees and cause their death, or whether in all cases the trees must be weakened from other causes before they are invaded by barkbeetles.

This subject has received special attention by the writer for many years and, so far as several American barkbeetles are concerned, it has been clearly and definitely demonstrated that healthy trees are attacked and that sometimes widespread devastations are the result of these primary attacks. It would appear, however, that the European species are much less aggressive in this respect and that there most of the instances of barkbeetle depredation have followed as the result of previous injury by storms or by defoliating insects, and that the barkbeetles were only able to extend their depredations into the living timber after they had increased to enormous numbers in the injured trees. However, as will be seen by the following, these insects have been the final cause of enormous losses by preventing the recovery of injured trees and by extending their ravages into the healthy forests, thereby causing the expenditure of large sums of money in efforts to control them.

EIGHT-TOOTHED PINE BARKBEETLE.—Among the species of this class, one, the so-called eight-toothed pine barkbeetle (*Tomicus typographus* L.), is worthy of special mention, since it is the one most frequently mentioned in connection with the more notable examples of destruction of timber by barkbeetles. It is a small, reddish-brown, cylindrical beetle, the body sparsely clothed with long hairs, and the posterior ends of the elytra, or wing covers, deeply excavated, the margin of the excavation being armed with eight processes or teeth, the third on each side much longer than the others.

The insect passes the winter in the bark of the trees, where the broods have developed during the preceding summer. The adults appear on the wing, according to Eichhoff, "about the time the buds begin to open on the beech trees, or in April and May;" they then enter the living or dying bark of felled, injured, or standing living trees and excavate longitudinal branching galleries through the inner bark. Along the sides of these galleries eggs are deposited, which hatch into small grubs, or larvæ. These larvæ extend their food burrows through the inner layers of bark until they have completed their larval development, in May and June; they then transform to the pupal stage, and in June and July to the adult stage, thus completing the first generation. The adults of this generation proceed,

as before, to attack other trees and deposit eggs, from which the second generation develops and emerges in August and September, to deposit more eggs for a partial third generation, which passes the winter in the larval stage.

Of all the species of barkbeetles that infest the coniferous trees of Europe this appears to be the most important in its relation to the dying of timber and especially the widespread devastation following an invasion of the "nonne" moth of the felling of timber over large areas by storms. Such large amounts of weakened and dying timber at successive intervals present the most favorable conditions for the multiplication of this and other allied species, which, through a combined attack, either prevent the recovery of trees which might otherwise survive, or invade the living timber and thus extend the devastations started from some other cause.

Among the notable examples of depredations said to have been caused by this species alone or in combination with other species and causes, the following are worthy of mention:

It appears from German literature that between 1781 and 1783 there was a great invasion of *Tomicus typographus* in the Harz Mountains, Germany, as a consequence of which more than 2,650,000 trees had to be cut down, and later extensive mining industries in the devastated region were jeopardized by the scarcity of fuel. It is also stated that the severest attacks of this beetle began with the second half of the nineteenth century, following the invasions of the "nonne" moth of that period, and continued until at least 1862. A little later (1864-1870) came a period of terribly destructive storms throughout central Germany, Bohemia, and eastern France. The exact dates of some of these storms are given as November 6 and December 7, 1868, and October 26-27, 1870. These storms provided an enormous amount of felled timber to attract the barkbeetles, which at that time must have occurred in the greatest abundance. In various sections of the countries mentioned we consequently find references to most extensive depredations, which continued in the most alarming manner until about 1875.

Oberförster Eichhoff stated that in the Bavarian forests approximately 700,000 "km." of timber died and that this species, in company with four other barkbeetles, occurred in such vast swarms as to obscure the sun. He states further that in one reserve 1,000 workmen were brought in from Bohemia and Italy for the felling and barking of the trees and in two years (1873 and 1874) 70,000 florins (about \$25,000) was thus expended.

It is stated by another author that the invasion of *Tomicus typographus* spread to alarming proportions and that the foresters of two countries put forth great efforts to guard against the invasion of the beetles by barking and promptly selling the wood of the fallen

trees; also, that after some 9,000 workmen had cut 2,700,000 cubic meters (95,348,000 cubic feet) of wood and in 1875 after having made a clean cut over more than 15,000 acres of surface and having cut down 300,000 trap trees, the invasion was brought to an end.

Another example of the same period is that contained in a translation by Hough from a special publication of the French forest administration issued in 1878. This relates to an extensive invasion by this and another barkbeetle in the spruce forests of the Jura Mountains following the storm of November 6, 1864. The depredations extended from the storm-felled to the standing timber and continued until 1872. It was not until 1869 and 1870, after more than 100,000 trees had perished, that proper measures based on entomological information were adopted, viz, felling and barking the infested trees before the broods of beetles had time to develop and emerge. By this means the insect was brought under complete control in 1872, after more than 181,000 trees had perished.

Twenty years later the writer visited a section in the Vosges Mountains, just north of the Jura, where a storm of March 30, 1892, had blown down some 500,000 spruce trees. To avoid a repetition of the barkbeetle invasion, every one of these trees had been promptly barked. This was a striking example of utilization of information gained from the experience mentioned above.

DANGER OF INTRODUCTION OF FOREST PESTS INTO AMERICA.

Already the gipsy moth, the brown-tail moth, the larch sawfly, and certain other insects injurious to the forest and shade trees of Europe have found their way into America, and, as usual, have proved far more destructive here than at home. Therefore it can be imagined what would happen if the "nonne" moth, the pine spinner, or the eight-toothed pine barkbeetle should become established in our pine and spruce forests, and especially in the National Forests of the Northwest, where the conditions would evidently be most favorable for their multiplication and destructive work. Therefore every evidence of the presence of a newly introduced pest should receive prompt attention.

DEPREDACTIONS IN NORTH AMERICA.

Very little is known in regard to the early history of depredations of forest insects in North America, but from what we now know of the principal enemies of forest trees in different sections of the United States and Canada and of the prevailing conditions as regards the distribution of tree species and the average age of the matured or veteran trees, it is evident that insects were one of the important factors in forest destruction and forest modifications during prehistoric times as they have been within the past century.

The principal enemies of the living trees of American forests, like those of Europe, fall into the two groups of defoliators and bark borers, but the latter are more important than the former, and both in number of species and in destructiveness they greatly exceed the same class of insects in Europe.

DEFOLIATING INSECTS.

The defoliators which have caused the more notable and widespread depredations in North America, concerning which we have definite records, are the larch worm, the pine butterfly, the hemlock spanworm, the forest tent caterpillar, the gipsy moth, and the brown-tail moth, among which the larch worm occupies first rank as a destroyer of trees in North America, although it occupies a minor position in Europe.

LARCH WORM.—The larch worm of North America and that of Europe are evidently the same species, but whether or not this insect was introduced into America within historic times or, like a number of other species, has always been common to the northern zones of both continents, can not be definitely determined. The fact, however, that it is more abundant and destructive in this country than in Europe would indicate that, like many of our worst farm, garden, and fruit-tree pests, it was introduced through the agency of man.

A summary of the evidence relating to this insect in North America indicates that there have been about five more or less extensive outbreaks since about 1853, as follows: 1853, in Quebec; 1881–1886, a great invasion extending from Maine into New York and over the whole of eastern Canada, from Labrador to about 30 miles west of Ottawa, the invasion ending suddenly in 1886; 1889–1891 and 1894–1898, locally from Prince Edward Island to New York and Guelph, Ontario; 1903–1907, a great invasion extending from eastern Canada westward to a point just north of the middle of Lake Superior, and locally through New England, westward to Wisconsin.

The aggregate area covered by these outbreaks appears to be that of the natural distribution of the American larch east of Wisconsin, or about 600,000 square miles, in which a large percentage of the so-called matured larch has been killed.

As regards the outbreaks of this insect in Europe within the past century, the recorded years and periods were as follows: 1827–1829 and 1839–1847, in Denmark; 1835–1838, in Holstein; 1880, in Siberia; 1892, in Sweden; 1894, in Norway; 1903, in Finland; 1906, in England. It appears, however, that it has never been so common and destructive in any European country as it has in North America, but perhaps this is because it has been less successful in its struggle with natural enemies in Europe than in this country. It is very evident,

however, that it has some natural enemies in this country, or at least that there are some natural influences which bring about a sudden and almost universal check to its ravages in a given section of the country after it has been very abundant for three or four years, otherwise the larch would have been practically eliminated from the northern forests. As yet no method has been discovered by which this insect can be controlled, but the natural methods of control are being investigated, with a hope of their successful utilization and promotion in the future.

PINE BUTTERFLY.—The pine butterfly (*Neophasia menapia* Felder) resembles in general appearance the common cabbage butterfly, though differing somewhat from that species in color, markings, and structure. The earliest reference to the extensive depredations by this insect was in 1882, at which time it was stated that over a large area in the vicinity of Spokane, Wash., all the yellow pine had been nearly or totally stripped of foliage, giving the forest the appearance of having been scorched by fire.

According to information furnished by Prof C. V. Piper, at the time professor of entomology at Pullman, Wash., about the year 1883, the butterflies were so numerous that the bay at Seattle was almost white with their floating bodies, and in 1890 they were very abundant in the Olympic Mountains, where in 1895, according to his further account, thousands of the dead bodies of the insects covered the ground.

In 1896 Doctor Fletcher observed an outbreak in the elevated plateau which forms the interior of British Columbia, on western yellow pine, and at Vancouver Island, on Douglas fir. It is further stated that two years previously (1894), at the snow line on Mount Hood, the butterflies were observed in large numbers hovering about the tops of the trees, and the next year whole acres of the nut pine (*Pinus monticola*) began to die, and that the insect made its appearance during 1895 on the pine timber on mountains near Golden-dale, Wash. During investigations of forest insects in the Boise Basin, Idaho, in 1905, an agent of the Bureau of Entomology was informed that in 1898 the dead butterflies occurred in such numbers as to dam the small streams. In 1899 the writer observed the 1898 work of the insect on western yellow pine in the Moscow or Cedar Mountains, Idaho. Here evidence was found that most of the trees would have recovered had they not been attacked by barkbeetles. Another agent of the Bureau was informed that in 1903 pine trees were defoliated on many square miles in southern Washington in the vicinity of Mount Adams, and in August, 1907, a correspondent reported the insect in large numbers on yellow pine in Spokane County, Wash., and another reported it from near Alpha, Idaho.

The insect has been recorded from California and Colorado northward into British Columbia. Evidently, while it appears at irregular intervals in such vast swarms as to attract general attention and vast areas of pine are often defoliated by the larvæ, its natural enemies prevent the continuance of its depredations in any one locality long enough to be independently destructive to the timber; yet it appears that the weakened condition, even from a slight defoliation, is sufficient in some cases to attract certain of the destructive bark-beetles, which are thus able to increase and start a new and more serious trouble like that following an invasion by the "nonne" moth in Europe.

THE GIPSY MOTH.—The gipsy moth (*Porthetria dispar*), brought by accident into the United States nearly forty years ago at a point near Boston, has spread throughout eastern Massachusetts into southern New Hampshire and southwestern Maine, and has also made its appearance at isolated points in Rhode Island and eastern Connecticut. Its damage to the large forests in this portion of the country has been very great, and its threatened spread into the timber forests northward has been for years the cause of much alarm. It appears in countless numbers, and the defoliation of the trees two years in succession frequently brings about their death. This is especially true of conifers. The loss it has occasioned by the actual destruction of forests, shade trees, fruit trees, and other vegetation is very great and must run into the millions of dollars. It has caused a great loss in the reduced value of real estate in the portions of the country infested. It has brought about an enormous pecuniary loss to holders of property from the expense of the war that has been waged against it. The State of Massachusetts alone has spent over \$2,000,000 in efforts to control the pest. When the insect was first discovered it is safe to say an immediate expenditure of less than \$100,000 would have stamped it out.

BARK-BORING INSECTS.

The most destructive enemies to coniferous trees are to be found among the barkbeetles. In this country there are several species which select prime healthy trees, avoiding in their attack those which are in an unhealthy or declining condition, thereby causing enormous losses, in many cases hardly to be estimated. In Europe the bark-beetles are almost without exception secondary in their infestation, preferring injured or weakened trees, and only attack those which are perfectly healthy when their numbers have enormously increased. Then by their repeated assaults even the most vigorous tree becomes so weakened as to fall an easy prey not only to the primary attackers but also to such secondary forms as may be present.

SPRUCE-DESTROYING BEETLE.—The spruce-destroying beetle (*Dendroctonus piceaperda* Hopk.) has proved itself one of the most

destructive species with which we have to deal. The earliest reference to dying spruce in the Northeast was in 1818, and another early record is 1831-32. About 1840 the mortality of spruce timber on the hills in the region of Newport, N. H., was very great, and ten years later (1850) the spruce was said to have turned red and died on about 500 acres in Irasburg, Vt. From that time to the present there are records of great destruction to the spruce forests throughout the Northeast. In 1897 Fiske found the spruce dying and infested with beetles in northern New Hampshire. In 1900 the subject was thoroughly investigated by the writer in the region north of the Rangely Lakes.

As a rule this species confines its attack to the older and more mature trees, killing them by excavating egg galleries which penetrate the cambium, or growing portion of the trunk, and cause a loss of the tree's vitality. The young larvæ, as they proceed from these primary galleries, form transverse burrows which destroy any cambium which may still be left, resulting in a rapid and complete destruction of the remaining life in the bark. The species extends from New Brunswick to New York, westward to the Lake Superior region, and northward into Canada. It attacks and kills the red, black, and white spruces, but only the larger trees. The amount of timber killed by it, as indicated by published accounts and the observations of the writer, has been very great; certainly within the last half century several billion feet of timber have been thus destroyed. Different authors and their correspondents have estimated for different areas the death of 10, 50, and as much as 90 per cent of the matured timber.

The results of the writer's investigations enable him to suggest a practical remedy, viz, the directing of the regular logging operations into the worst infested timber, so that infested trees can be cut and floated out. The adoption of this method has proved very satisfactory west of the Rangely Lakes, resulting in the saving of over \$100,000.

ENGELMANN SPRUCE BEETLE.—The Engelmann spruce beetle, as its name indicates, attacks the Engelmann spruce, often causing immense losses through its depredations. Like the preceding species, it attacks only the larger or matured trees, and evidently is the most important enemy of the Rocky Mountain spruces. From time to time it has caused widespread depredations, which were extended by great forest fires starting in the dead timber. Through an investigation made by the Bureau of Entomology in the Sierra Blanca Mountains of the Lincoln National Forest, New Mexico, it was found that 75 to 90 per cent of the spruce over an area of several thousand acres had been killed by this beetle. Another invasion which occurred some fifty years ago was particularly striking in the southern slopes

of Pikes Peak, Colo., at an altitude of about 10,000 feet, where nearly all of the timber had been killed by the ravages of this insect.

BLACK HILLS BEETLE.—The Black Hills beetle (*Dendroctonus ponderosæ* Hopk.), with habits similar to those of the preceding, causes the most serious of losses in forests. It occurs in the eastern sections of the Rocky Mountain region from the Black Hills of South Dakota to southern Arizona.

It was stated that in 1897-98 in the region of the Black Hills there were rectangular patches of dead timber on the tops of the divide or ridges and running up and down the slopes. The situation was investigated by the writer in 1901, when it was found that the depredations were caused by an undescribed species. An exhaustive report, based on these observations, was made in the fall of that year. Subsequent observations have proved it to be one of the most destructive enemies of forests, choosing, as it does, for its attack, sound, healthy trees in preference to those of lesser vigor and health. Wherever this insect is found in abnormal numbers its depredations on living timber are more or less extensive. It has killed between 700,000,000 and 1,000,000,000 feet of timber in the Black Hills National Forest, and is also demonstrating its destructive powers in Colorado and northern New Mexico. The methods recommended for the control of this beetle have been successfully applied in the vicinity of Colorado Springs and in a large Spanish grant in southern Colorado, where by felling and barking some 50 to 75 per cent of the infested trees the broods were destroyed and the insect so reduced in numbers that it could not continue its depredations. Thus, at a comparatively small expense, widespread invasion was evidently prevented.

MOUNTAIN PINE BEETLE.—The mountain pine beetle, also an undescribed species, resembles the preceding very closely, both in appearance and habits. It attacks injured, felled, and living silver pine, sugar pine, western yellow pine, and lodgepole pine. It extends north of Colorado and Utah westward to the Cascades and southward through the Sierra Nevadas. While this species sometimes apparently prefers to attack injured and felled trees, it is often found attacking and killing the living timber over vast areas. As an example of its depredations, through investigations made by the Bureau of Entomology, it has been found that in northeastern Oregon 90 or 95 per cent of mature lodgepole pine and yellow pine has been killed within the last three years over an area of more than 100,000 acres. It is very evident that this beetle has been an important factor in the destruction of matured forests in the Northwest in past years.

WESTERN PINE BEETLE.—The western pine beetle (*Dendroctonus brevicomis* Lec.) is especially destructive to the western yellow pine

in central Idaho and in the mountains and higher valleys of eastern Washington, Oregon, and California. As a rule, the largest and best trees are attacked; the winding primary galleries beneath the bark soon serve to girdle the tree and kill it, even before the broods of young have completed their development and emerged. The commercial value of the wood of trees killed by this barkbeetle is reduced by the bluing of the sapwood, even before the leaves begin to turn yellow. Thus the loss from the work of this beetle has been enormous.

DESTRUCTIVE PINE BEETLE.—The destructive pine beetle (*Dendroctonus frontalis* Zimm.), through its ravages, causes large and severe losses. A destructive invasion which occurred in 1890–1892, as determined by the writer, extended from the western border of West Virginia through Maryland and Virginia, into the District of Columbia, northward into Pennsylvania, and southward into western North Carolina, an area of over 75,000 square miles, in which a very large percentage of young trees, as well as the matured trees, of pine and spruce was killed by it. In many places in West Virginia and Virginia nearly all the pine trees of all sizes were killed on thousands of acres, while shade and ornamental trees within the same area suffered the same as those in the forest. The total destruction of the pine and spruce of the entire area was threatened, but the severe freeze of December, 1892, and January, 1893, together with natural enemies, exterminated the pest or so reduced its numbers that no more timber has died on account of its ravages in that region since 1893. It has been more or less active in the States south of Virginia to Texas since 1902. In some localities and during some years it has killed a large amount of timber. The species may be considered as one of the most dangerous enemies and a constant menace to the pine forests of the Southern States. Records of extensive dying of timber in the Southern States are found dating back to the early part of the nineteenth century, and evidence now proves conclusively that these depredations were caused by this beetle.

HICKORY BARK-BORER.—The hickory bark-borer (*Scolytus quadrispinosus* Say) has within recent years been the cause of enormous losses of hickory timber throughout the northern tier of States from Wisconsin to Vermont and southward through the eastern Atlantic States as far as central Georgia. While this beetle is very destructive and causes extensive losses, successful methods of combating it have been recommended. As an instance, the utilization of these methods in Belle Isle Park, at Detroit, Mich., proved very efficient and resulted in the saving of the valuable hickory trees on that island from any further depredations by this pest.

LOCUST BORER.—The locust borer (*Cyrtene robiniae* Forst.) is one of the most destructive wood borers. The larvæ penetrate the wood oftentimes to such a degree that it becomes literally honeycombed with their galleries. In fact, so extensive is the damage to natural growth, artificial plantations, and shade trees that in some sections within the natural range of the tree in the Eastern States, but particularly in the Middle West, where both the tree and the insect have been introduced, it is considered unprofitable to grow the tree for shade or timber. If the trees are not seriously attacked, the timber often attains sufficient size for use as posts before it suffers enough to be rendered worthless for such purposes.

CONCLUDING REMARKS.

A striking feature of nearly all of the great invasions by forest insects in Europe and this country has been their more or less periodical nature, and the more or less sudden check of the outbreak after a large percentage of the timber had been killed and within two or three years after the insect had become so abundant as to threaten the total destruction of the kind of trees attacked by them. This is to be explained by various natural causes, which, however, operate only after the greatest damage has been done, and often the invasion is far beyond human control. Therefore the object in future management of forests should be to utilize the authentic technical information relating to the species involved and the vital features in their seasonal history and habits, with a view to preventing destructive outbreaks or promptly adopting the proper measures for their control as soon as the first evidence of the insects' presence in destructive numbers is noted. In fact, the first evidence of an outbreak of a destructive insect should receive the same prompt attention as that required in preventing the spread of an incipient forest fire. Fortunately most of the barkbeetles can be kept under complete control with little or no expense by proper adjustments in forest management and lumbering operations.

The history of efforts toward the control of forest insect depredations in Europe as well as in this country shows that one of the greatest obstacles has been the failure to realize the importance of expert entomological information. This has resulted in the waste of time, energy, and large sums of money in absolutely worthless and often detrimental efforts before proper measures have been adopted and applied.