THE SPRUCE BUDWORM

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The spruce budworm is a small, foliage-feeding caterpillar that periodically kills an immense amount of spruce and balsam fir in the Eastern States and Canada. It is serious in jack pine in the Lake States, and in Douglas-fir, alpine fir, white fir, Engelmann spruce, blue spruce, lodgepole pine, and ponderosa pine in the West.

It is native to North America. Records of its ravages in the East date from about 1805. It appeared again in epidemic proportions about 1880.

The first outbreak to be studied carefully began in Quebec in 1909, appeared in Maine in 1910 and in New Brunswick and Minnesota in 1913, continued for nearly a decade, and destroyed more than 250 million cords of spruce and fir pulpwood. About 30 million cords were killed in Maine; in Minnesota, more than 20 million cords were destroyed.

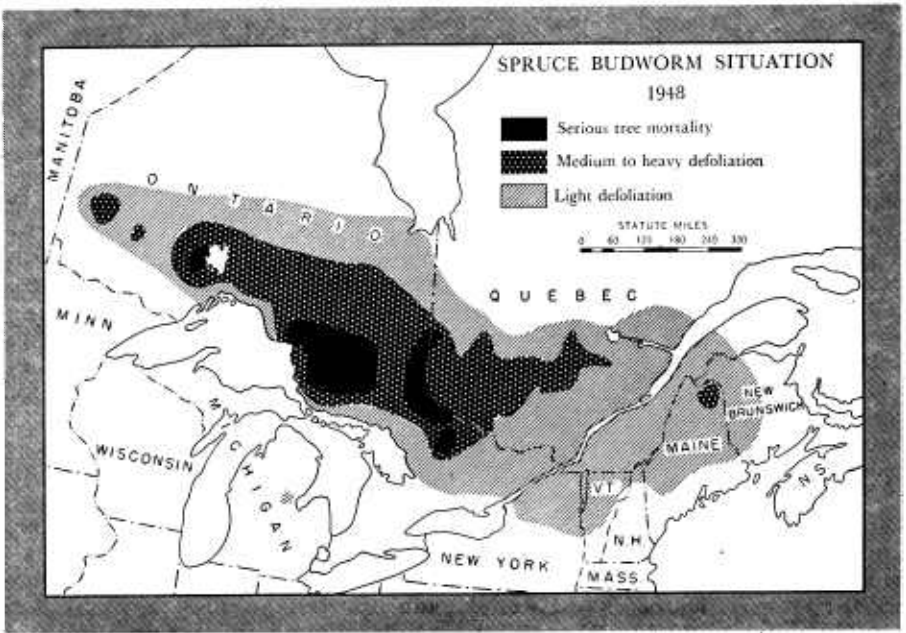
But all that devastation, all that destruction may be nothing compared to a current outbreak in Canada that began to assume epidemic proportions in 1935. By 1944, it was estimated, 125 million acres in Ontario were infested. In 1945, an official of a Canadian pulp and paper company said, the insect killed enough timber to supply all Canadian pulp mills for 3 years. By 1947 most of the mature fir and a considerable part of the white spruce on an estimated 20,000 square miles had been killed, with less intense damage over a much larger area. The dead trees have created a tremendous fire hazard; large areas affected by the budworm already have been burned.

The memory of the previous outbreak in Maine and the present situation in Canada have caused great alarm among owners of timberland and officials of the pulp and paper industry in the Northeast. At stake in the region are nearly 19 million acres of spruce-fir and more than 100 million cords of pulpwood. On that timber supply depend more than 90 mills, which have an annual capacity of 3½ million cords, employ more than 55,000 workers, and manufacture goods worth more than 300 million dollars annually.

BECAUSE OF THE SERIOUS THREAT to the pulp and paper industry, the timberland owners asked Congress for funds to find ways to control the insect and to prevent widespread damage such as had occurred in Canada. The funds were voted, and in July 1944, two units of the Department of Agriculture, the Bureau of Entomology and Plant Quarantine and the Forest Service, began a program to study the problem in all its phases and develop a plan of action for the Northeast. Surveys in which the States cooperated indicated that few specimens of the spruce budworm were present then in New England forests.

But in 1945 we discovered an infestation in the Adirondacks of New York. The next year we found many more, and an outbreak seemed imminent. In 1947 and 1948, however, the population of spruce budworm dropped markedly. Over most of the area, defoliation was not severe enough to cause appreciable damage to spruce and fir. During 1945, 1946, and 1947, the insect remained at an extremely low population level in Vermont, New Hampshire, and Maine. The 1948 survey showed a low degree of abundance in Vermont and New Hampshire but a definite increase in Maine. No report of unusual abundance of the budworm has been received from the Lake States. Extensive outbreaks were in progress in 1948 in the southern, central, and northern Rocky Mountain regions and in Oregon and Washington.

From 1945 to 1948 intensive studies in biological and natural control of the insect were conducted in New York.



Plots and experimental areas were established in the Northeast to determine the degree of defoliation and damage caused under different forest conditions. In the Rocky Mountains there are several species of parasites of the budworm that do not occur in the East; several colonies of those parasites were obtained and released in eastern forests in the hope that they would become established.

THE SPRUCE-FIR STANDS in the Adirondacks, relatively small in area, usually are surrounded by hardwoods. Such stands seem particularly favorable for natural control. Winter mortality during 1946–47 was approximately 75 percent. Aggregate parasitization by insect enemies ranged from 64 to 86 percent in different area. The total aggregate mortality from winterkill and parasites ranged from 83 to 98 percent. Insectivorous birds also destroyed large numbers of budworm larvae and pupae. Certainly those factors of natural control contributed tremendously in bringing about the decline in budworm infestation in 1947 in New York.

THE SEASONAL HISTORY of a pest must be known before control measures can be undertaken.

The adult of the spruce budworm is a small moth with a wing spread of seven-eighths of an inch. Its general color is grayish with brown markings.

In the Northeastern States the moths start emerging from their pupal cases about July 1. The females deposit their pale-green eggs on the foliage in masses of 10 to 50 or more, where they overlap like the scales of a fish. One female may lay several of these egg masses and on the average produces about 175 eggs. The incubation period lasts about 10 days.

After the eggs hatch, the young caterpillars crawl about until they find suitable places under bark or bud scales to spin silken weblike coverings, or hibernacula, under which they spend the following fall and winter. These tiny larvae do not feed until they become active in late April or early May and leave their hibernacula. At first they are an orange yellow; later they turn brownish. They mine the old needles first; then they enter the opening

buds, where they feed on the tender young needles which are just starting growth. They also feed on spruce and fir pollen. As the new shoots elongate, the larvae tie the needles together with silken threads and thus form shelters within which they feed. By late June they are full-grown, reddish brown in color, and start forming the pupal cases, which are attached to the twigs. The pupal period lasts 7 to 10 days, after which the moths emerge and start laying eggs—a new generation is under way.

The spruce budworm may spread over long distances to new areas by flights of the moths. Records of the 1910–19 outbreak show that in July 1911 swarms of moths appeared in Philadelphia and in 1912 and 1913 they were abundant in Connecticut. Those localities are outside the general spruce-fir range, so the presence of the moths there had significance only in showing how far they travel.

The regions where extensive tree mortality has already occurred in the present outbreak and the extent of the active infestations are shown on the accompanying map. There is no record of a flight of moths in 1944 from Canada that might have caused the outbreak conditions discovered in New York in 1945. Apparently, though, a heavy infestation arose simultaneously over an area of approximately 3,000 square miles, and careful study of the area in 1945 pointed strongly to the possibility of a widespread flight of moths in 1944.

DURING AN OUTBREAK PERIOD, a heavily infested tree may harbor thousands of caterpillars. Except when the young caterpillars first resume activity in the spring and form mines in the old needles, the new foliage is the preferred food and it is entirely devoured before the old foliage is eaten.

In heavy infestations the trees first exhibit a scorched appearance. Later they turn grayish as the foliage disappears. Finally dead tops become evident. A heavy defoliation for several years will reduce the volume of foliage to a degree where many of the caterpillars die from starvation and the budworm population declines, but in the meantime many of the trees will have died. Following the decline of the insect in a particular area, the loss of trees continues for several years, because secondary insects and fungi have a part in killing weakened trees.

The feeding habits of the spruce budworm determine to a large measure the damage in various types of stands.

The caterpillars show a definite preference for fir in that they develop readily on both old and current growth. Although the budworm feeds readily and develops rapidly on pollen from fir trees, the presence or absence of abundant staminate flowers has little effect on the budworm population in the forest. The lack of synchronism between budworm development and opening of buds and the poor survival on old foliage of red and black spruce indicate that these two species are less favorable food plants than balsam fir. This fundamental information on the biology and feeding habits of the spruce budworm and the fact that mortality in all species of attacked trees is directly proportional to the lack of vigor at the time of defoliation give us a basis for formulating methods for the silvicultural control of this insect.

Investigations made during and after the disastrous outbreak of 1910–19 in New Brunswick and Maine indicated that the greatest mortality of trees occurred in the red spruce-balsam fir type, particularly where the fir predominated and was overmature.

Little damage occurred in the mixed hardwood-spruce fir stands, where the hardwoods overtopped the conifers.

White and black spruce appeared to suffer less from attack than red spruce and fir.

THE RESULTS of the earlier studies and the intensive work of Canadian and American entomologists during the present outbreak point the way toward a possible solution.

To view the problem in perspective, one might well review some of the factors that have brought about the present condition of the spruce-fir forests.

Because spruce is far more valuable for lumber and pulp than balsam fir, it has been cut more heavily in logging and pulpwood operations and its proportion in the forests has thus been reduced. Balsam is far more aggressive than spruce in seeding-in after a cutting operation, fire, or wind damage. Foresters repeatedly have observed that after a serious budworm outbreak the succeeding stand invariably contains a higher proportion of balsam. Man's activity and the spruce budworm, therefore, have often contributed to a gradual conversion from a forest containing a high percentage of spruce to one in which balsam predominates and which is far more favorable for the budworm.

In view of such points, then, what can be done through silvicultural practices to increase the resistance of the forest to spruce budworm attack?

There appear to be three general procedures: To clear cut mature and over-mature balsam stands; to operate balsam stands on a short rotation; to try to increase the proportion of spruce in the stand.

The first and second would be aimed at keeping existing stands of fir as young and vigorous as possible. Mature and overmature balsam fir trees suffer most during an outbreak. It is not because their foliage is more palatable to budworm caterpillars than the leaves of more vigorous trees, but because they are low in vigor and cannot survive severe defoliation. The clear cutting of such stands should be given first priority in a plan of action.

In a long-range program to build up the resistance to future budworm outbreaks, consideration needs to be given to two major types of stands, those that are predominantly balsam fir and those that contain an appreciable proportion of spruce.

In a stand that is mostly balsam, cutting on a rotation of 30 or preferably 20 years will help to maintain the stand in a condition of high vigor. Such a stand may harbor a heavy population of budworms, but it will suffer much less than a stand of low vigor. The operation of such a stand on short rotation will at the same time greatly increase the ultimate yield.

Where spruce occupies an appreciable proportion of the stand, every effort should be made through cutting operations to increase the proportion of spruce and at the same time save only the balsam firs that are very vigorous.

In order to demonstrate these cutting methods, experimental areas are being established jointly by the Forest Service, the Bureau of Entomology and Plant Quarantine, the States, and the owners of timberland in the Northeast. The areas are cruised and marked by the Federal agencies and operated by industry. They are located in several parts of the region, so that the influences and different site and stand conditions can be observed.

In these silvicultural operations, the latest findings from the biological studies are put into practice. We hope that the experimental areas will become a pattern for future commercial operations so that resistant forests eventually will be established all over the Northeast.

IN SUM, then, we know that each new epidemic is far more disastrous than the last, and that now the spruce-fir resources of this country and Canada are in jeopardy.

Aerial applications of insecticides offer new possibilities for controlling defoliators like the spruce budworm; further attempts to control the insect over extensive areas by aerial spraying are now in progress and will be continued during the present outbreak.

But all studies and observations by entomologists and foresters suggest that the ultimate solution lies in managing the forest so as to maintain high vigor in balsam fir stands and, where conditions permit, to increase the proportion of spruce. Every effort should be made to obtain the basic biological

information useful in developing silvicultural practices that will create conditions unfavorable for the development of outbreaks or minimize damage during an outbreak.

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PINE BARK BEETLES

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Pine bark beetles are small, dark-colored, hard-shelled insects of the size of a grain of rice or a medium-sized bean. They bore under the bark of various pines and dig egg tunnels, mostly in the inner bark, which cut the cambium layer—a tree's most vital tissue. Eggs laid along the sides of these tunnels hatch into small, white, legless grubs. Under the bark also the attacking beetles introduce fungi, blue stains, and yeasts, which penetrate the sapwood and plug the sap stream from roots to foliage. The tree is hurt in the same way that an animal would be injured or killed if worms were to bore into it and stop up all veins and arteries.

When the larvae complete their feeding in the inner bark, they change into pupae, the resting stage, then to new adults. These adults later emerge from the bark and fly off to attack other pines. Thus they perpetuate their species and continue their destructive course. The new adults may attack the green trees nearby, or they may fly several miles to find trees to attack.

A great many different kinds of beetles work into and under the bark of pines. The most destructive bark beetle enemies of American forest trees are the so-called pine beetles (*Dendroctonus* spp.), which attack primarily the more mature trees, and engraver beetles (*Ips* spp.), which prefer young trees or the tops of older ones. Species of *Dendroctonus* and *Ips* are found throughout North America.

The more important species of *Dendroctonus* that attack pine are the western pine beetle (*D. brevicomis* Lec.), which attacks ponderosa pine and Coulter pine in the Pacific States, Idaho, Montana, and British Columbia; the southern pine beetle (*D. frontalis* Zimm.), which attacks all species of pines and spruce from Pennsylvania south to Florida and west to Arkansas and Texas; the mountain pine beetle (*D. monticolae* Hopk.), which attacks lodgepole pine, western white pine, sugar pine, and other pines in the Pacific States and northern Rocky Mountain regions; the Black Hills beetle (*D. ponderosae* Hopk.), which attacks ponderosa and lodgepole pines in the southern and central Rocky Mountain regions and in the Black Hills of South Dakota; the Jeffrey pine beetle (*D. jeffreyi* Hopk.), which attacks Jeffrey pine in California; and the turpentine beetles (*D.*