SILVICULTURAL CONTROL OF THE GYPSY MOTH

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Published by the

MASSACHUSETTS FOREST AND PARK ASSOCIATION

3 Joy Street, Boston, Massachusetts

August 1936

Price 50 cents

Foreword

Extensive outbreaks of the gypsy moth in recent years, especially in central and western Massachusetts have led to renewed efforts to find a more economical method of dealing with this tree pest. It is recognized that eradication of this insect is impossible and that we must contend with it indefinitely. We know that shade trees can be protected by the methods now in use, but in woodlands the expense of control is limited by the financial or other benefits that may result from such control.

Elimination of favored food trees has long been practiced as a means of control, but the authors of this bulletin have gone a step further and have shown how the owner may so treat his forest as to serve the double purpose of moth control and stand improvement. In other words, the control of this pest, except in special cases, need not add greatly to the cost of producing a commercial crop. Through the publication of this bulletin the Massachusetts Forest and Park Association believes that it may encourage many woodland owners to apply this form of silviculture with profitable results.

WILLIAM P. WHARTON, President

HARRIS A. REYNOLDS, Secretary

DISTRIBUTION AND IMPORTANCE

The gypsy moth (*Porthetria dispar L.*) was introduced into this country 67 years ago, and for the last 47 years it has been a pest of great importance. Today practically all of New England excepting the northern half of Maine is infested to some extent. With initial infestation in the vicinity of Boston, and early spread into southeastern Massachusetts, the direction of most rapid spread, as indicated in Figure 1, has been toward the Northeast, no doubt a result of prevailing winds in this direction during the hatching season when young larvae are known to be carried by the wind.

To prevent western spread of the insect from New England, a Barrier Zone 30 miles wide and extending from the Canadian border to Long Island Sound was established by the Federal Government in 1923. The zone lies in western New England and in New York state, east of the Hudson River. (See Figure 1). Here scouting is carried on continuously and all infestations discovered are promptly eradicated. Thus, the limits of infestation reached in 1925 have since been pushed back to the eastern boundary of the zone. Outside of New England isolated areas of infestation have required special attention. An early infestation of considerable size in northern New Jersey has been completely eliminated; in northeastern Pennsylvania another large infestation more recently discovered is being vigorously attacked by the Bureau of Entomology and Plant Quarantine in cooperation with the State. In addition, many local infestations west of the Barrier Zone have been promptly eliminated.

Infestation within the area reached by the gypsy moth has been by no means uniform. Eastern Massachusetts, southeastern New Hampshire, and southwestern Maine have been especially susceptible to attack. But even in towns rated as most heavily infested many individual stands have entirely escaped severe defoliation. Westward extension of the area subject to epidemic outbreaks appeared to have ceased by 1920. However, in 1934-1935 a new outbreak occurred in Massachusetts west of the region formerly subjected to severe defoliation but still east of the Connecticut River.

Outbreaks of both a regional and local character occur at irregular intervals, and it is the severity and frequency of these outbreaks which determine the economic importance of the insect. Thrifty hardwoods are never killed by a single defoliation, but the loss of vigor occasioned by repeated defoliation may pave the way for other pests and often leads to considerable mortality. On the other hand, a single complete defoliation usually proves fatal to conifers (with the exception of larch). Aside from actual loss of trees, protection of aesthetic values is of major importance in residential sections, along roadsides, and in woodland recreational areas.

CONTROL

Broadly speaking, two types of control of the gypsy moth may be recognized; namely, biological control and artificial control.

Biological control may develop naturally when outbreaks have attained epidemic proportions through a disease known as "the wilt", or through starvation resulting from complete defoliation before the larvae have matured. The latter is always localized in areas of heavy infestation. Biological control may also be brought about through introduction of parasitic and predaceous enemies of the gypsy moth

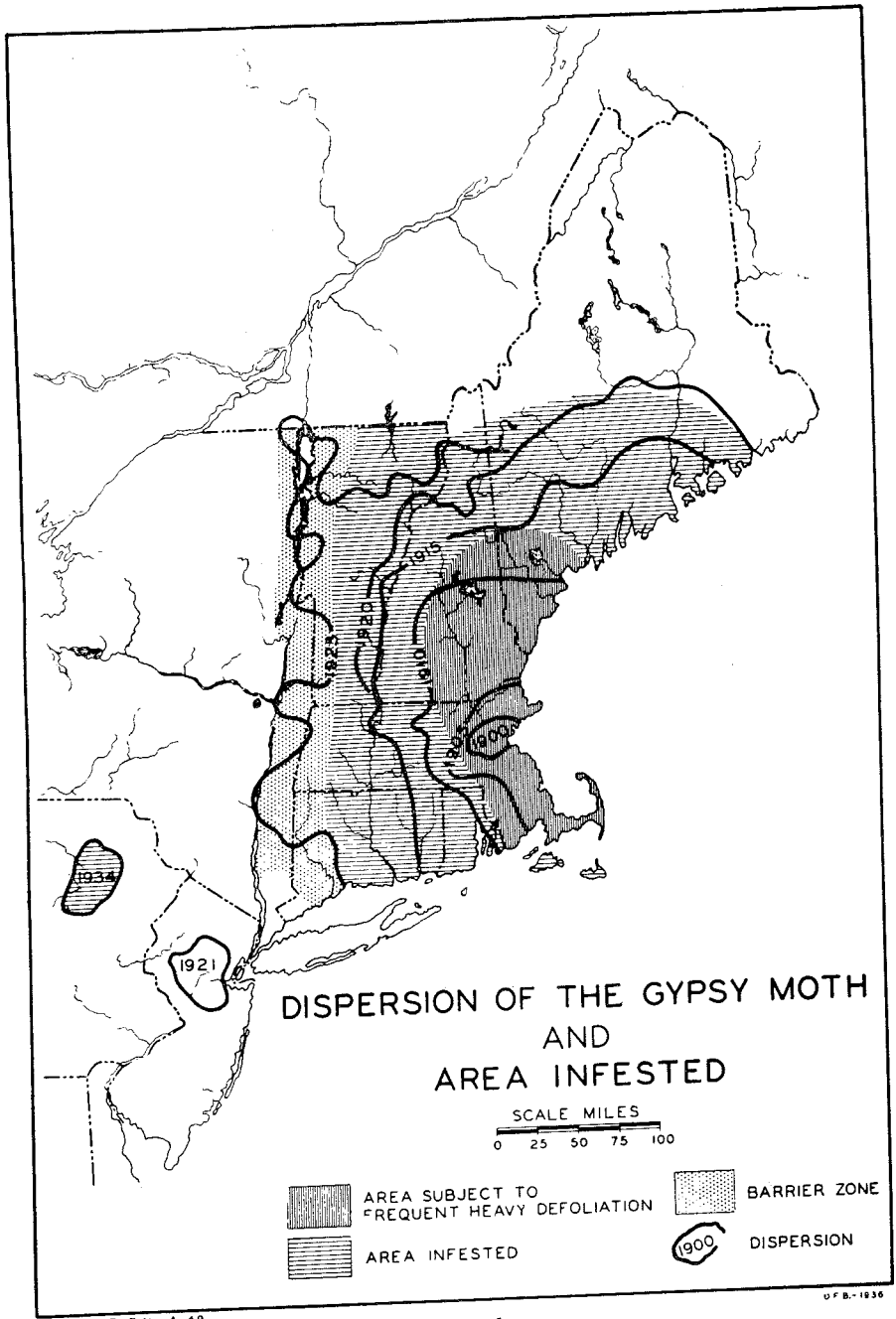
1915
1920
1925
1910
1905
1900
1934
1921
DISPERSION OF THE GYPSY MOTH
AND
AREA INFESTED
SCALE MILES
0 25 50 75 100
AREA SUBJECT TO FREQUENT HEAVY DEFOLIATION
AREA INFESTED
BARRIER ZONE
1900 DISPERSION
U F B.-1936
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Figure 1

from its native habitat in the old world. This has been given major emphasis by the Federal Government for many years. Parasitization is especially effective within the lightly infested areas, where it serves to minimize the intensity of, and lengthen the period between outbreaks. Since epidemic outbreaks recur from time to time in spite of these biological factors, every effort should be made to control the insect by other means.

Artificial control is concerned chiefly with the destruction of the insect either in the egg or the larval stage. In the egg stage, control measures are mostly confined to creosoting over-wintering egg masses, and in the larval stage to the application of poison sprays (lead arsenate) to the foliage. In addition migrant larvae may be prevented from ascending the trees by bands of tanglefoot, or larvae may be destroyed as they gather in bands of burlap folded around the tree trunks. When thoroughly applied, these methods are effective in protecting trees from injurious defoliation; however, the nature and cost of the work involved usually limits their application within the generally infested area to streets and roadsides, camp sites and other areas of intensive use, or to spots where incipient outbreaks need to be held in check. If applied over extensive forest areas, their cost would soon far exceed the value of the property; and with the funds ordinarily available for such work, it is exceedingly doubtful whether effective results may be expected. At best, these methods of artificial control are only palliative. None of them contributes in any permanent way toward elimination of future epidemic outbreaks. They are measures designed to reduce infestations as they arise, without respect to conditions favoring the development and spread of moth populations.

A key to a gradual but more permanent measure of control applicable over a considerable part of the infested territory is found in the discrimination in feeding habits of the gypsy moth larvae. The larvae exhibit a marked preference for the foliage of certain species, and infestations will not attain epidemic proportions in the absence of these favored species.* By silvicultural measures the prevalence of favored food species can be reduced and the growth of less favored food species encouraged. The cost of such silvicultural control will generally be commensurate with the values at stake and indeed may often be more than repaid by the improved quality and stimulated growth of the residual forest crop.

FEEDING HABITS

Early studies of feeding habits of the gypsy moth have been the basis for such selective thinning as has been practiced by the Bureau of Entomology and Plant Quarantine for many years. The forest trees of New England may be classified as food for the gypsy moth as follows:**

(1) Species highly favored by larvae in all stages —

oak (all species),	river birch
alder	poplar (all species)
gray birch	box elder
basswood	hawthorn
willow	apple

*Craighead, F. C. and Collins, C. W., Statement Presented at Conference on Gypsy Moth. Bur. of Ent. and Plant. Quar. Wash. D.C., Dec. 1934.

**For a more complete list see: Mosher, F. H. Food Plants of the Gypsy Moth in America. U. S. Dept. Agr. Bull. 250, 39 pp., 6 pl., 1915 (revised).

(2) Species favored in all larval stages, but distinctly less so than those under 1 —

paper birch
larch (all species)

(3) Species edible in all larval stages, but not favored (usually ignored in the presence of species under 1 and 2) —

maple (all species)
yellow birch
black birch
elm
sassafras
hickory (all species)
black gum
hornbeam
black cherry

(4) Species definitely unfavorable in early larval stages but highly favored by larger caterpillars —

pine (all species)
hemlock
southern white cedar
beech
spruce (all eastern species)

(5) Species not favored in any larval stage —

ash
locust
tulip tree
butternut
red cedar
black walnut
dogwood
american holly
balsam
sycamore

Stands composed entirely of species in class 1 may be completely defoliated. Stands of species in class 2 may also be infested, but the likelihood of complete defoliation is distinctly less than in pure stands of class 1 trees. Stands restricted to the species in class 3 are at times lightly infested, but cases of heavy defoliation are extremely rare. Infestation cannot originate in stands composed entirely of species in class 4, and stands restricted to the species in class 5 are practically immune.

Mixtures of classes 1 and 2 are highly susceptible to heavy defoliation. Mixtures of 1 and 3 are susceptible only when the proportion of foliage in class 1 is high enough to allow a large number of larvae to enter the later stages of development in a vigorous condition. In such mixtures trees in class 1 are usually entirely defoliated before those in class 3 are severely attacked. In mixtures of classes 1 and 4 the defoliation of the latter is also dependent upon the proportion of class 1 trees present. If sufficient class 1 foliage is available for the larvae to reach the third stage of development in a healthy condition, trees in class 4 may be severely attacked. Mixtures of classes 2, 3, 4, and 5 are seldom defoliated, although the likelihood is greater than in mixtures of 3, 4, and 5.

The dependence of the gypsy moth on the distribution and abundance of favored food species has been clearly established by the Bureau of Entomology and Plant Quarantine from observations over a 10-year period (1912-1921) on 104 woodland plots in the eastern portion of the infested area. Figure 2, which gives the results of this study, shows a definite increase in both number of egg clusters per acre and degree of defoliation associated with an increase in the proportion of favored food species.

This evidence is corroborated by a study of 81 of the 82 completely defoliated stands in the town of Petersham, Massachusetts, in 1935.* In every case highly favored food species comprised over 50 percent of the stand. Furthermore, in several cases where an area of complete defoliation was sharply delineated within a continuous forest this was associated with a distinct change in composition from predominantly favored to predominantly unfavored species.

The severity of recent outbreaks in central Massachusetts indicates the inadequacy of the creosoting program and brings out the desirability of placing increased emphasis on silvicultural control. To the extent that composition of the forest can be altered so that favored food species do not constitute a dominant element in the stand, the danger of having to deal with a major outbreak will be substantially reduced.

THE RELATION BETWEEN PROPORTION OF FAVORED FOOD PLANTS IN THE STAND AND INTENSITY OF GIPSY MOTH INFESTATION AND DEFOLIATION. RECORDS FROM 104 WOODLAND PLOTS FOR A 10 YEAR PERIOD. 1912–1921.

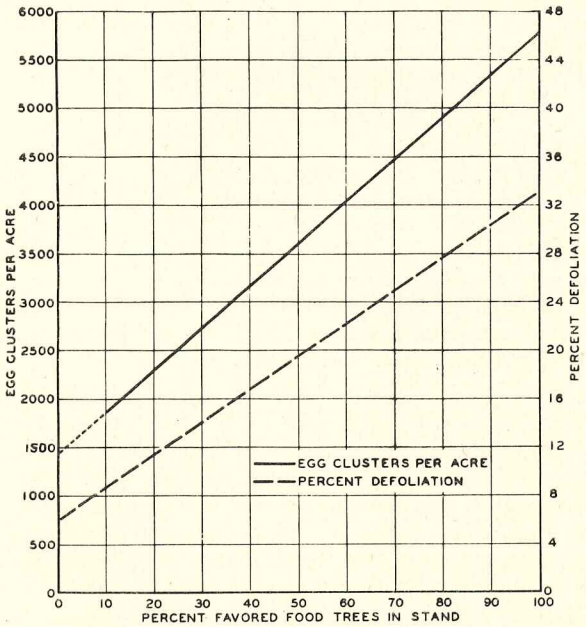

Figure 2.

BASIS FOR SILVICULTURAL CONTROL

Changes in Forest Types Have Favored Gypsy Moth

Consideration of the past history of the forests of New England in relation to their present condition supports the belief that the forest can be rendered far less susceptible to gypsy moth attack than at present. With few exceptions the original forest types contained smaller percentages of favored food species than

*Baker, W. L., and Cline, A. C. A Study of the Gypsy Moth in the Town of Petersham, Mass., in 1935. Journal of Forestry, Vol. 34, No. 38.

the secondary types which have followed as a result of cutting, burning and clearing.

Cutting of white pine from the original forests tended to increase the proportion of hardwood. In the area infested by the gypsy moth, oaks were the principal species benefited in this process. Abandonment of lands used for agriculture prior to the opening of the West gave rise to large areas of even-aged, second growth pine in central New England. Clear-cutting of these stands during the past thirty years, with fire often sweeping the cut-over land, has further favored an increase in the proportion of oak, and has been accompanied by a tremendous increase in the prevalence of gray birch and poplar. Because of the diminished supply of pine seed, these latter inferior species have also tended to dominate more and more the forest growth taking possession of old fields and pastures.

Thus it becomes evident that the forest types which present most favorable conditions for gypsy moth attack are the direct result of a transient agriculture and the destructive lumbering practices of the past.

Forest Improvement Generally Provides Protection from Gypsy Moth

At the same time, unrestricted and profligate use of the forests of New England for more than two centuries has left them in seriously depleted and deteriorated condition. In addition to an influx of inferior species, cutting of immature hardwoods has given rise to stands of rank-growing stump sprouts, and the leaving of inferior trees in logging operations has encumbered the new stands with overtopping and worthless wolf-trees. Yet, despite such abuse, the present stands often contain enough good trees to make possible the development of desirable timber crops. There is perhaps no other part of the country where the forests will benefit more by silvicultural treatment, and restoration of forest values is an essential feature of economic land use in this region.

To a very large extent, measures aimed at silvicultural improvement of the forest will also serve to minimize danger of gypsy moth attack and, vice versa, recommendations for rendering the forest less favorable to gypsy moth will generally be consistent with desirable silvicultural practice. This is not only the case with weedings and improvement cuttings in young stands, but also in the proper management of older stands, where the substitution of partial cutting for the clear-cutting practices so prevalent in the past may be expected to reduce the abundance of the light-demanding weed species most favored by the gypsy moth.

Thus the need for aggressive action to protect the forests from gypsy moth should stimulate proper silvicultural treatment of long-neglected forests, and the prospect of substantially adding to economic values through such forest improvement may translate a large part of the necessary cost into a worthwhile investment for the future.

FOREST REGIONS IN RELATION TO GYPSY MOTH CONTROL

Because of characteristic differences in the composition of the forests in different portions of the infested area, the problem of silvicultural control, both as to initial danger of infestation and opportunity to reduce susceptibility, varies widely. A brief discussion of the major forest regions, as outlined in Figure 3, is therefore essential to consideration of possible control measures.

Northern Hardwood Region (Northern Forest)

The forest of northern New England and northern New York is predominantly composed of beech, sugar maple, and yellow birch with lesser quantities of soft maple, white ash, basswood, and paper birch. Red spruce and balsam fir are the leading conifers but white pine and hemlock are also widespread in occurrence.

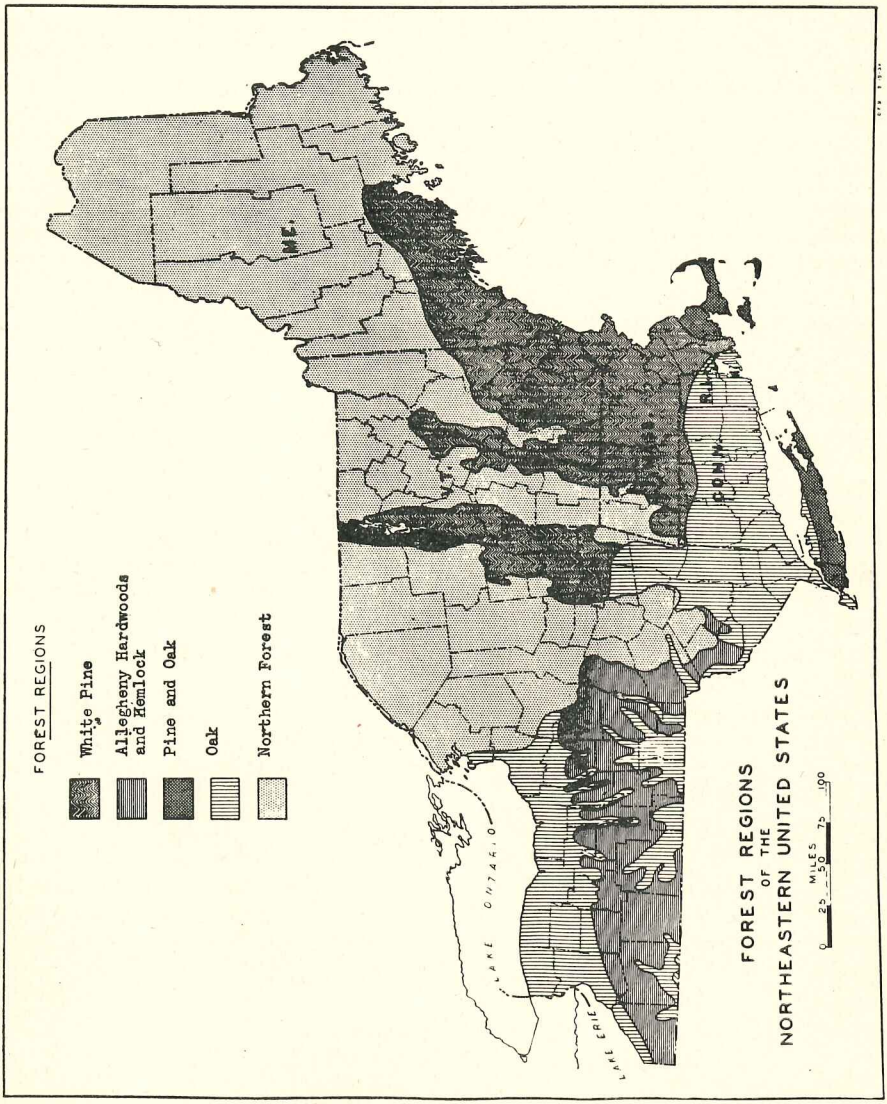

Figure 3

This region extends from near the mouth of the Penobscot River in Maine westward to the White Mountains and central highlands of New Hampshire and thence southward through the Green Mountains of Vermont to the Berkshire Hills of western Massachusetts.

In its natural state this northern region is resistant to gypsy moth attack, and even on old burns, abandoned fields and recently cut-over lands where stands of favored food species such as poplar and paper birch predominate serious outbreaks have been rare. Without doubt, climatic factors operate in much of the Northern Hardwood region to hold the gypsy moth in check. Effort at silvicultural control may well be confined largely to the lower elevations and to the southern extension of this region, where climatic conditions are perhaps less effective. Drastic reduction of favored food species here should greatly simplify the task of maintaining the Barrier Zone inviolate.

Central Hardwood Region (Oak)

The forest of southern New England comprising Connecticut, Rhode Island, and irregular extensions into Massachusetts is part of the Central Hardwood region in which oak predominates. Along with several species of oak will be found hickory, maple, and a great variety of other hardwoods. On the better soils white ash and a few of the southern species such as tulip poplar occur, while on the dry, rocky ridges the stand may be composed almost entirely of chestnut oak. Over large areas of upland, oak and hickory form nearly pure stands. On many abandoned fields and pastures gray birch is a characteristic and widespread element in the stand.

In contrast to the Northern Hardwood region, the forests of the Central Hardwood region are composed very largely of species highly favored as food by the gypsy moth, and this complicates the problem of obtaining effective control through silvicultural measures. Up to the present, however, there have been few serious outbreaks in this region. Factors other than food, but not now understood, have doubtless prevented epidemic outbreaks. Since substantial reduction of favored food species will be impracticable in most of the older stands of this region, effort may well be directed toward the elimination of gray birch, poplar, and alder from "old field" stands, and the encouragement of resistant species in the treatment of young stands of whatever character.

Cape Cod Region (Pine and Oak)

Cape Cod constitutes the northern extremity of the Pine and Oak region of the Middle Atlantic Seaboard. The soils are generally sandy and the forest conditions are similar to those found on the lighter soils in the Central Hardwood region, except for the greater prevalence of pitch pine and "scrub" oak. But the climate is more equable, and this region has been subjected to as frequent and severe outbreaks of the gypsy moth as any other portion of the infested area. The dearth of resistant species affords little opportunity for silvicultural control except by clear-cutting and planting.

White Pine Region

That portion of New England commonly designated as the White Pine region coincides rather closely with the area which has been subject to most severe gypsy moth attack. It extends from Cape Cod west and north through most of Massachusetts, southern New Hampshire, and southwestern Maine, with a narrow strip along the eastern shore of Lake Champlain which has been subject only to local infestation.

Although white pine is the characteristic tree of this region, the forests are only dominated by this species on areas of light, sandy soils and to some extent on abandoned farm land. Various species of hardwood, hemlock, and pitch pine are often more abundant than white pine. On the ridges and drier soils of southeastern and central Massachusetts the hardwood species most prevalent are those characteristic of the Central Hardwood region to the south. In New Hampshire and Maine the hardwood species associated with white pine include those commonly found in the Northern Hardwood region. The meeting and intermingling of these "northern" and "central" species in north central Massachusetts and southern New Hampshire have given rise to what is known as the transition forest zone. Since the death of chestnut, red oak is one of the most abundant and aggressive of the better hardwood species in this zone. Throughout the region, gray birch and poplar occur over extensive areas, particularly on the poorer soils and on fields and pastures abandoned in recent years.

Because of the great variety of commercially valuable species present, many of them resistant to gypsy moth attack, there is a much greater opportunity for silvicultural control than in the Central Hardwood region to the south, and a much greater need for such work than in the region to the north.

THE APPLICATION OF SILVICULTURAL MEASURES OF CONTROL

Principles

Silvicultural measures for control of the gypsy moth should follow essentially the same principles as have been developed for forest improvement work in general. The principles and techniques which should govern weeding and improvement cuttings are fully covered in earlier bulletins by A. C. Cline* and only a brief statement is needed here.

In initiating forest improvement work, attention is first centered on the selection of such well-formed trees of desirable species as promise to make the best possible final crop. The species to favor will vary with factors of soil and climate, as well as desires of the owner. In the case of hardwoods, seedlings or seedling sprouts, rather than stump sprouts, should be favored wherever available. All trees overtopping or likely to overtop those selected as crop trees should be cut or girdled. Subordinate trees needed to help prune the crop trees, to protect the soil or to maintain an adequate forest canopy should be left standing.

Improvement cuttings, of any sort, should be as light as may be consistent with their purpose, and it is frequently necessary to exercise restraint in order to avoid making too large an opening in the canopy. The poor quality of many trees and the prevalence of sprout clumps and weed species often makes it difficult to select a sufficient number of desirable crop trees for a complete stand. In such cases cutting should be restricted to giving the crop trees optimum conditions for growth, and to the cutting of such highly favored food trees as may be removed without unduly exposing the soil. Complete removal of all favored food trees may have to be delayed for subsequent operations, undertaken after a lapse of several years.

If the number of desirable crop trees available in stands up to pole size is insufficient to make up a satisfactory proportion of a stand at maturity (say less

* A. C. Cline "Forest Weeding". 20 pp. illus. Mass. Forestry Association, 1929.
"Improvement Cutting and Thinning". 16 pp. illus. Mass. Forest and Park Association, 1935.

than 50 trees per acre), the only opportunity for restoring productive conditions will be through clear cutting and planting.

Reasonable security against serious defoliation by the gypsy moth generally will be attained when the volume of favored food tree foliage does not constitute more than 50 percent of the total. In striving for this objective, due consideration should be given to the dispersion of the favored species in the stand. Serious defoliation may develop in sizable groups of highly favored food species even though these groups may occupy only a small portion of the entire area.

Priorities

In the following paragraphs silvicultural control in stands of various kinds is taken up in a descending order of importance from the standpoint of probability of loss in relation to investment or timber values involved.

These priorities would not apply within the Barrier Zone, where the object is to exterminate the insect whenever and wherever it appears. However, the silvicultural practices suggested below may well be applied in connection with control operations in the Barrier Zone, although more drastic cuttings may be justified there than in the generally infested area.

For a given ownership, priority in treatment of various areas will also depend, of course, on the degree of infestation present or in prospect. Treatment should be carried out in advance of severe attack, due warning of which is possible by examining susceptible stands from time to time to see how many egg masses are present. Where the number exceeds 1,000 per acre, some measure of protection is indicated. Where it reaches 5,000 or more, heavy defoliation is likely to occur. Since infestations normally build up over a period of years, stands lightly infested one year should be closely watched in succeeding years.

Coniferous Plantations

Coniferous plantations are placed first in the list of priority for treatment, because of the comparatively large investment at stake and the inability of conifers (with the exception of larch) to refoliate following attack. The conditions under which coniferous plantations may be subject to damage are chiefly (1) old fields and pastures where such favored food trees as gray birch and poplar are growing among the conifers and (2) cut-over land, especially the lighter soils, where these same species, and oftentimes oak, are present. Quite frequently the competing hardwood growth, usually of little or no value and not intended as part of the crop, overtops the planted trees, and the unsatisfactory condition of many plantations is plainly the result of failure to clear the site in advance of planting or of neglect to weed.

The protection of plantations or stands of natural origin of any of the conifers, except larch and blue spruce, can be assured by the removal of intermingling or surrounding trees of species highly favored by the gypsy moth, because the caterpillars cannot survive on the foliage of any of the conifers, except larch and blue spruce, during the first two larval stages. The principal need is the removal of those hardwoods which are overtopping the conifers. Hardwoods subordinate in height are of less concern. In some cases a hardwood "filler" is used intentionally for the purpose of improving the quality of the conifers, but this is kept in its place, namely, below and not above the conifers. However, a filler consisting largely of species highly favored by the gypsy moth should be avoided, especially

within the generally infested area. If composed of both favored and unfavored food trees, the former should be cut out, or at least reduced to a minor portion of the whole.

Coniferous Understories

Throughout the White Pine region, growth on abandoned fields and pastures frequently consists of an understory of white pine in competition with inferior hardwoods of favored food species. Similar conditions are found in the case of white pine with oak, of hemlock with oak in the White Pine and Central Hardwood regions, and of spruce and balsam with poplar and paper birch in the Northern Hardwood region. Coniferous understories have also been established to some extent in New England by planting, especially on the lighter soils, where hardwood growth is relatively slow, and under light-foliaged species such as poplar and gray birch.

Security from gypsy moth demands removal of the hard-wood overstory, if of favored food trees, before a moth colony becomes established. Such cutting of the overstory may upset earlier plans to reduce white pine weevil attack through the effect of partial shade, or to wait until the overstory trees have reached the best size for utilization; but such losses are of little significance compared to severe or complete defoliation of the conifers. However, it must be pointed out that sudden and complete removal of an overstory in cases where the conifers have been weakened through long suppression may result in serious damage from snow and ice. "Releasing" under such conditions might well be taken in two steps: in the first, reducing the hardwood overstory by about one-half, leaving sufficient cover to lend protection to the conifers until they have strengthened their boles; and in the second, made a few years later, removing all of the remaining overstory. To the extent that species other than those favored by the gypsy moth make up the overstory, the cutting may be correspondingly lightened and the period of removal lengthened.

Isolation Strips for Coniferous Stands

The removal of favored food trees from coniferous stands should be supplemented by cutting a protective strip wherever stands of such hardwoods adjoin the coniferous stands. While conditions for the migration of gypsy moth caterpillars across open areas vary considerably with factors of larval size, ground cover, etc., a cleared strip about 100 feet wide is thought to be sufficient to prevent any serious defoliation in the margin of a coniferous stand. Sprout growth on these strips should be cut back before it reaches large sapling size. Where poplar is the species involved, root-suckering, which invariably follows cutting, may be largely avoided by girdling intead of cutting. This should be done by stripping off a wide band of bark rather than by cutting a notch, in order to avoid the danger of windthrow before the energy required for sprouting has been exhausted.

In the case of adjoining stands of mixed character, only the highly favored food trees need be removed, or at least reduced to a minor proportion of the whole. The width of such "thinned" strips will depend upon many factors, and beyond suggesting that they should be wider than cleared strips, specific recommendations cannot be given at present.

Mixed Conifers and Hardwoods

Mixtures of conifers and hardwoods, more or less uniform as to size of trees, will be found in all parts of New England. In the treatment of such mixtures, protection of the conifers will generally be the primary consideration. Mixtures

of pine with gray birch, poplar or oak in the White Pine region present the major problem. In the Central Hardwood region mixtures of hemlock and oak, and in the Northern Hardwood region mixtures of spruce and balsam or pine with poplar must be considered. The extensive areas of spruce and balsam in mixture with birch, beech, and maple in the Northern Hardwood region will call for little, if any, treatment.

In middle-aged or maturing stands the conifers usually are not defoliated to such an extent that they die, except where they form a very minor element in the mixture with favored food species. However, when the gypsy moth population is approaching outbreak proportions in the vicinity and heavy defoliation of valuable conifers is anticipated, protective treatment should be applied in the form of a cutting to reduce the quantity of highly favored hardwood foliage. Reduction of such foliage to at least one-half of the foliage volume of the conifers will probably assure freedom from serious damage. Where conditions of ownership and markets permit, complete removal of the highly favored hardwoods may be desirable. Openings resulting from the cutting may be planted with resistant species, if natural restocking does not prove satisfactory.

Where conifers occur in mixture with a variety of both favored and unfavored hardwoods, less drastic cutting will be needed. Here the amount of highly favored hardwood foliage may be reduced in proportion to the combined total of coniferous and unfavored hardwood foliage, particular attention being paid to the amount and distribution of the conifers. It should be understood that reduction to the extent recommended is the minimum which will serve to prevent appreciable loss of conifers from defoliation. In all cases the degree of security will depend upon the relative freedom of the residual stand from highly favored food trees.

Young stands of conifers and hardwoods in the sapling stages offer excellent opportunity for treatments to reduce the danger from gypsy moth. They deserve special attention because, in the absence of protective treatment, the conifers may be severely damaged or killed.

On the heavy soils in the White Pine region where young, groupwise mixtures of conifers and better hardwoods, including a large proportion of oak, are developing, security may demand a reduction in the amount of highly favored foliage to less than half the total for all hardwoods in a given group. Almost invariably there is a large variety of hardwoods available for the crop, and cutting out some of the poorest oak in favor of such species as white ash, sugar maple, black cherry, yellow birch, and tulip poplar is considered highly desirable from a silvicultural standpoint.

On lighter soils, where conifers and hardwoods grow at similar rates and may therefore be in stemwise mixtures, and where the hardwood element may consist almost wholly of oaks, it would be advisable to cut the oaks and plant conifers in their place. By planting a different species from that already established, a mixed coniferous stand could be developed. Similar consideration would apply in mixtures of spruce and balsam with poplar in the Northern Hardwood region, but it would be preferable to girdle the poplar by stripping the bark rather than to cut it down.

Mixed Hardwoods of Commercial Importance

Stands composed entirely of hardwood species of commercial importance vary widely in their composition and, consequently, in their susceptibility to gypsy moth attack and in the feasibility of effecting control through silvicultural measures.

Mixtures of yellow birch, beech, and maple, the predominant species in the Northern Hardwood region, present no problem because little damage by the gypsy moth is ever likely to occur.

In hardwood mixtures of the transition forest zone, the abundance of oak, together with an increased proportion of gray birch and poplar, introduces an element of danger. However, the number of other species present usually is so great that the proportion of oak and other favored food trees, including paper birch, may readily be reduced without lessening the final value of the crop. In these mixtures species to be encouraged as a measure of protection against the gypsy moth include white ash, sugar maple, yellow birch, hickory, and black cherry. Stands under 30 years of age will be found much better adapted to such treatment than older ones, since in the latter suppression of other species by the oak may have passed beyond a remediable stage. Every consideration — crop security, probable future markets, and sound silviculture — dictates favoring a well-balanced mixture of several of the better species, and over most of the transition zone this means a reduction in the proportion of oak, as well as the elimination of the "weed" species.

In southern New England mixed hardwood stands are even more predominantly oak. The only species in the unfavored class showing an increase are hickory and tulip poplar, the former being very common on the drier sites and the latter being restricted to the better sites. Protective measures should aim at a gradual reduction in the amount of oak and other favored foliage, to an upper limit of one-half of the total for the stand. Several relatively light periodic cuttings may be necessary to accomplish the purpose; and during this period of alteration of composition, the density of stocking may be kept up by favoring (in addition to the better hardwoods) such species as red maple and black birch, which, though of secondary commercial importance, are not highly favored food trees.

In instances where the stand is composed almost entirely of oak, the most promising solution lies in clear-cutting by groups followed by the planting of unfavored hardwood species from classes 3 and 5. Planting pine or spruce is unsafe because these conifers could not be protected from infestations which might develop in the adjacent oak groups. Periodic application of group cuttings will eventually serve to convert the stand into a relatively immune group selection form in which oak would be limited to a minor representation. As that condition is approached, pine and spruce could be added to the list of species suitable for planting in the clear-cut openings. Such a plan is probably best adapted to young stands where the difference in age between the residual oak groups and the initial plantings would not be more than 20 years. It is suggested because it does not involve immediate liquidation or complete sacrifice of existing values in young growing timber.

Where a ready market is available, merchantable stands of oak might be converted at one stroke to an even-aged form resistant to gypsy moth by clear-cutting and planting. Conifers may be used for the planting over a wide range of conditions, but resistant hardwoods are suggested for the heavier soils. Two or three weedings of the planted stands will be necessary to insure satisfactory development. In these no attempt should be made to eliminate the oak, but rather the objective should be to develop a mixed stand of conifers and hardwoods in which the volume of oak foliage is not more than half as much as that of the coniferous foliage, or, in the case of heavier soils where hardwoods have been planted, a composition in which oak does not exceed one-half the total foliage volume.

Non-Commercial Hardwoods

In the aggregate a considerable area in New England supports stands entirely or predominantly of inferior species such as gray birch, poplar, and "scrub" oak, all of which are highly favored by the gypsy moth. Of the species named, "scrub" oak, which includes low quality growth of several commercial oaks as well as burr oak and other scrub species, is most common in the southern part of the area infested by the gypsy moth, especially on Cape Cod. Gray birch is most characteristic in the White Pine region, and poplar forms extensive stands in the north.

In stands of this sort there is plainly only one form of silvicultural treatment which will contribute toward control of the gypsy moth, namely, clear-cutting followed by planting. As in the conversion of commercial oak stands, hardwoods of unfavored species or mixtures of such hardwoods and conifers may be used on the best sites, while only conifers are adapted to the lighter soils and drier sites. In these stands also timely weeding of gray birch or oak stump sprouts and poplar root suckers is necessary from the standpoint of both silviculture and gypsy moth control.

Although in themselves these non-commercial stands have no values worth protecting, their replacement by stands of resistant species of commercial importance may be amply justified. Such conversion will afford protection to adjacent forests by reducing the area where gypsy moth outbreaks are likely to develop, and will serve to restore the areas concerned to productive use.

CONCLUSIONS

Consideration of the history of the gypsy moth and of existing forest conditions in New England leads to the conclusion that, in spite of all control effort to date, epidemic outbreaks with serious defoliation may continue to occur within the infested area.

Parasitization serves to reduce the severity and frequency of outbreaks, but may not be counted upon to prevent their occurrence. Measures of artificial control, involving painting of egg clusters and spraying, are of value when properly planned, especially in situations where aesthetic values are paramount. They are indispensable for checking incipient outbreaks within the Barrier Zone. Because of the high cost of artificial control when applied over extensive areas of forest, increased emphasis should be placed on silvicultural control measures to develop stands which will be resistant to gypsy moth attack by reducing the proportion of species favored as food by the larvae. Information based on averages over a period of many years and secured from a large number of woodland plots shows that in mixtures of hardwoods serious defoliation is not likely to take place where the volume of favored food tree foliage constitutes less than one-half the total, but, where the protection of conifers is involved, a somewhat greater reduction is recommended. Where conditions are particularly favorable for increase of the insect, it may be advisable to reduce still further the volume of favored foliage, perhaps even to the extent of complete elimination.

Increasing the proportion of woodland in which conditions are unfavorable for the development of the insect should lessen the need for artificial control and reduce the frequency and severity of outbreaks. By holding infestation within bounds, silvicultural control also maintains conditions under which parasitization is most effective. With few exceptions, elimination or reduction of highly favored food species will conform to desirable silvicultural practices. Silvicultural control, therefore, has the added advantage of serving the objectives of forest improvement.

August, 1936.