UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE
DIVISION OF GYPSY AND BROWN-TAIL MOTHS CONTROL

THE VALUE OF GYPSY MOTH CONTROL AND EXTERMINATION TO UNINFESTED REGIONS OF THE UNITED STATES

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Work in preventing the spread of the gypsy moth by the U. S. Department of Agriculture was begun in 1906 as a result of insistence by the New England States that Federal help be extended in combating this introduced pest. For 10 years prior to 1900 the State of Massachusetts had made an attempt, single handed, to exterminate the insect from the territory covering about 200 square miles around Boston. This work was discontinued as a result of apathy on the part of the public because the insect had been reduced so that no visible injury could be noted, the antagonism of certain elements who opposed it, and continued failure to finance the program adequately so as to assure eventual success. Subsequent experience in dealing with this insect clearly justifies the belief that if adequate financial support had been given and the work continued the infestation could have been entirely eradicated in this country.

The tremendous increase and spread of the insect, during the five years after the work was discontinued caused public demands for relief from unbearable conditions, and, after the State of Massachusetts had made appropriations aggregating $375,000 and passed a law requiring property owners to clear up infestation on their own premises, an appeal to the Federal Government was given favorable consideration and work was begun with the primary object of preventing the spread of the insect. Restrictions were placed on the movement of products likely to carry the pest, parasites and natural enemies were introduced from foreign countries, part of the expense being borne by the State of Massachusetts, and clean-up work along the principal lines of travel out of the infested area was carried on for a number of years to prevent long-distance spread through vehicular means. The introduction and breeding of many species of parasites was continued, and they were colonized in the infested territory as rapidly as possible. In 1913, after the passage of the Federal Plant Quarantine Act, the infested territory was placed under Federal quarantine requiring the inspection and certification of freedom from infestation of products moving beyond the known infested area. By this time all the New England States were involved, but only a few infestations had been found in Vermont and Connecticut. Federal field operations were confined to the outlying area, it being the policy of the States to confine their efforts to cleaning up the older infested territory.

A large amount of experimental work was conducted to improve the field methods which had been worked out in previous years by the State of Massachusetts. New facts were discovered in connection with the feeding habits of the insect, and advantage was taken of this information in connection with the removal of trees that were most susceptible to infestation and the encouragement of those species that were least attacked by the insect.

Improvement in field methods and the development of high-pressure spraying resulted. Facts concerning the spread of the insect by the wind were determined. They indicated that for the eastern part of New England the main drift of small caterpillars immediately after hatching was usually toward the north or northeast.

During the war period conditions were unfavorable for preventing spread. The loss of efficient personnel and the constant turnover of men, together with extraordinary increase in costs, made progress difficult. By the fall of 1922 scattered colonies were found farther west in Vermont, Massachusetts, and Connecticut, and in New York State near the Massachusetts State line. There was every indication of the continued spread of the insect unless more intensive work was done. A conference was held at Albany, N. Y., attended by entomologists from all the States concerned, the Bureau of Entomology at Washington, and the Dominion entomologist's office in Canada, to discuss the situation. It was decided that a control area, afterwards designated as a barrier zone, should be established, about 30 miles in width, extending from the Canadian border to Long Island Sound, and bounded on the west by the Hudson River. About one-half was located in New York and the balance in western Vermont, Massachusetts, and Connecticut. The purpose was to keep it as free as possible from infestation, thereby preventing the westward spread of the insect. The work has been financed by the Federal Government, although the State of New York, through its own organization, takes care of most of the work in this strip in its own State, while the other States assume responsibility for the control of the insect east of the zone.

In July 1920 a large infestation had been found in northern New Jersey covering over 400 square miles. Work was carried on as an extermination project in cooperation with the State Department of Agriculture, and in June 1932, after repeatedly scouting and treating all infestations in the original and surrounding area embracing over 2,300 square miles, the Bureau of Entomology discontinued operations. Work has been carried on since that time by a small force employed by the State. A small infestation was found in 1933. It has been cleaned up, and no infestation has been found in the State since 1935.

Another serious infestation was found in northeastern Pennsylvania in 1932, and work in cooperation with the Bureau of Plant Industry of that State has been under way since that time. No defoliation has resulted since the year of its discovery. The area under State quarantine is approximately 1,000 square miles, and a surrounding area of 1,500 square miles will require additional inspection as the work of eliminating the insect proceeds from the outer rim toward the center of the original infestation.

Since the barrier zone was established, small colonies have been found on Long Island, in the Bronx in New York City, and at several points adjoining or directly west of the zone. Most of these have been exterminated, while in others the work is nearing completion.

The original barrier zone contained 9,400 square miles. Since it was established a number of areas have been added east of the zone, embracing 1,500 square miles in Vermont and Connecticut, making a total of 10,900 square miles. Areas on the west side of the zone, particularly in northern New York, Vermont and southern Connecticut, have been found free from infestation, and periodic inspections have been discontinued.

Prior to the discovery of the heavy infestation in Pennsylvania in 1932, regular funds required for this work were reduced 37 per cent and they have never been increased. Beginning in 1934, emergency funds were allotted for use on Federal gypsy moth projects in all the New England States, New York, New Jersey, and Pennsylvania.

Protective work has been done between the Connecticut River and the barrier zone in Vermont, Massachusetts, and Connecticut by W.P.A. labor and details from C.C.C. camps, and this combined work has reduced many serious infestations during this period.

For 16 years the maintenance of this zone and the clean-up of outlying infestations have prevented general westward spread of the insect and have eliminated the necessity for the States, aside from those now affected, to spend funds for its control or to suffer loss of trees or injury due to defoliation. The entire cost to the Federal Government from regular and emergency funds for 33 years of operation has averaged less than $700,000 per year, and the cost to infested States to maintain partial control of the insect has averaged over $1,000,000 annually. Most of the latter funds have been expended for control of the insect on street and shade trees and in parks, playgrounds, and in residential areas. If the idea is sound that "an ounce of prevention is worth a pound of cure", then the funds which have been expended by the Federal Government for protecting the rest of the United States from this insect have paid large dividends.

The present situation is very serious, and if other sections of the United States wish to receive the protection which has been given them in the past, these facts should be considered carefully. Since 1934 most of the personnel used on gypsy moth work, aside from general or district supervision, has been supplied from relief rolls. Since 1936, when the number of these employees reached more than 5,000, the force has been decreased progressively until this year, when less than 800 are employed. This force consists not only of laborers who for the most part are competent, under supervision, to do the work to which they are assigned, but also includes scouts who do inspection work to find infestations and the foremen of crews who direct this work under general supervision. The regular supervisory force has faced a tremendous task to train relief men for this work, particularly because there has been a heavy turn-over in employees. The relief employees are not a mobile force as the men are required to work locally. In many sections of the territory, particularly in the large forested areas where most of the Federal work is done, there is a very sparse population, and it is impossible to cover all the territory that should be examined on account of the location of the personnel.

Work conducted within the zone the first year after its establishment showed that numerous scattered infestations were present in the New England and New York portions. Intensive control work, consisting of scouting to locate infestations, the destruction of all gypsy moth egg clusters found and the spraying of the heaviest colonies, greatly decreased the number of infestations, and by 1930 the zone area, with the exception of southwestern Massachusetts, northwestern Connecticut and adjacent New York, was apparently free from infestation.

During the last few years infestation has built up, and large areas have been defoliated directly east of the Connecticut River, except in the State of Connecticut, and similar areas have developed during the last two years between the Connecticut River and the barrier zone in Vermont, Massachusetts, and Connecticut in spite of the fact that all of the force available has been utilized in these States.

During the last two or three seasons there has been some wind spread of small caterpillars into the zone. This is indicated by a considerable number of single egg-cluster infestations. Since the eggs were deposited in July 1939 some scouting has been done in the zone, and an unusually large number of single egg-cluster infestations have been found in towns in Vermont, Massachusetts, and Connecticut and a smaller number in the New York section of the zone. In addition to favorable conditions for wind spread, it is now evident that the hurricane which swept through New England in September 1938 has contributed to the spread of the insect to a far greater extent than was appreciated at the time. While the amount of timber that was blown down or uprooted in and near the zone was not so great as in many sections east of the Connecticut River, it is apparant, from the general course of this tremendous wind storm, that egg clusters must have spread into the zone area, to some extent at least, on leaves, bark, or other material, and that this is a contributing factor in bringing about the condition that has been found during the last few months.

Normal employment has increased in much of the territory, particularly in the industrial and manufacturing sections of the zone area. It is now impossible to secure W.P.A. labor in some sections, and as the expenditures that can be made for all nonlabor purposes under W.P.A. funds are based on man-months of labor performed, the volume of work is reduced, and sufficient equipment or supplies cannot be procured.

This project has been glad to utilize unemployed labor during the emergency through which the country has been passing, but it is clear that, unless thorough work is done in the sections where it is urgently needed, including the small infestations in the zone, the zone which was created to serve as a barrier, and the exterminative work which is being carried on in northeastern Pennsylvania, the most westerly infestation known in the United States, will fail to protect the rest of the country.

Too much emphasis cannot be placed on the fact that the money spent by the Federal Government for the prevention of spread of the insect has furnished low-cost insurance for uninfested States and the cost of treatment and loss of trees will increase rapidly if it spreads beyond the

territory it now occupies. It is of vital importance to uninfested States that this work which is their principal means of protection from this pest should be maintained at the highest possible degree of efficiency.

The expenditures made by the New England States are solely for immediate protection of the more valuable shade and ornamental trees and this work must be done annually.

In areas which are generally infested the cost of artificial control in woodlands is usually prohibitive and the loss of trees and retardation of growth caused by the insect exacts a heavy annual toll.

It would seem that the States which have been protected for many years should interest themselves in this project if they desire a continuance of this protection. As a matter of conservation and good economics it would seem desirable to keep this insect in the territory where it is now established, and thereby prevent damage to other parts of the country.

OFFICE OF

BOARD OF SELECTMEN

PHILLIPSTON, MASS.

Notice to Property Owner

You are hereby required on or before Dec. 1, ~~1908~~ 1909, to destroy the gypsy and brown tail moths on your property in this town.

This notification is in accordance with chapter 381, Acts of 1905, as amended by Chapter 268, Acts of 1906, which requires cities and towns to destroy the eggs, caterpillars, pupæ and nests of the gypsy and brown tail moths under heavy penalty for failure to comply with the provisions of the law.

If a property owner fails to destroy such eggs, caterpillars, pupæ and nests, then the city or town is required to destroy the same, and the cost of the work, in whole or in part, according to the value of the land, is assessed upon and becomes a lien on the land. (See Section 6, Chapter 381, on reverse.)

The selectmen ask owners and tenants to co-operate with the town in its work on highways and other public grounds by doing effective work on their premises. Citizens who have cleaned their premises of the moths, but find their trees endangered by the neglect of owners of adjoining estates should make complaint to the Selectmen. The infestation of a residential neighborhood by the neglect of a few will not be tolerated.

The eggs of the gypsy moth should be destroyed at once with creosote. They should never be scraped off the object on which they are laid. Careful search should be made for gypsy moth egg clusters, not only on the trees but also on house walls, stone walls, fences and in rubbish heaps, etc. Trees in which cavities occur and which it is not desirable to cut should have the cavities tinned or cemented. This is important. The present and future cost of combating this insect can be greatly reduced by cutting and burning worthless brush, hollow trees, etc. A few trees well cared for are more valuable to the property owner and the community than a large number of neglected trees.

The nests of the brown tail moth should be cut from the trees, carefully collected and burned in a stove or furnace.

Full instruction as to best methods of work against the moths may be obtained from the Local Superintendent,

or from the State Superintendent, Room 1010, 6 Beacon Street, Boston, Mass.

Work done by contractors should be inspected and approved by Local Superintendent before payment for the same is made.

D W Baker

E F Smith

G M Chaffin *Selectmen.*

Date Sept 25, 1909

[CHAPTER 381, ACTS OF 1905, AS AMENDED BY CHAPTER 268, ACTS OF 1906.]

AN ACT TO PROVIDE FOR SURPRESSING THE GYPSY AND BROWN TAIL MOTHS.

SECTION 6. The mayor of every city and the selectmen of every town shall, on or before the first day of November in each year, and at such other times as he or they shall see fit, or as the state superintendent may order, cause a notice to be sent to the owner or owners, so far as can be ascertained, of every parcel of land therein which is infested with said moths; or, if such notification appears to be impracticable, then by posting such notice on said parcels of land, requiring that the eggs, caterpillars, pupæ and nests of said moths shall be destroyed within a time specified in the notice.

When in the opinion of the mayor or selectmen, the cost of destroying such eggs, caterpillars, pupæ and nests on lands contiguous and held under one ownership in a city or town shall exceed one half of one per cent of the assessed value of said lands, then a part of said premises on which said eggs, caterpillars, pupæ or nests shall be destroyed may be designated in such notice, and such requirement shall not apply to the remainder of said premises. The mayor or selectmen may designate the manner in which such work shall be done, but all work done under this section shall be subject to the approval of the state superintendent.

If the owner or owners shall fail to destroy such eggs, caterpillars, pupæ or nests in accordance with the reqirements of the said notice, then the city or town, acting by the public officer or board of such city or town designated or appointed as aforesaid, shall, subject to the approval of the said superintendent, destroy the same, and the amount actually expended thereon, not exceeding one half of one per cent of the assessed valuation of said lands, as heretofore specified in this section, shall be assessed upon the said lands; and such an amount in addition as shall be required shall be apportioned between the city or town and the Commonwealth in accordance with the provisions of section four of this act. The amounts to be assessed upon private estates as herein provided shall be assessed and collected, and shall be a lien on said estates, in the same manner and with the same effect as is provided in the case of assessments for street watering.

FOREST TYPE SURVEY

W. L. BAKER

An extensive survey for obtaining detailed information on the distribution and abundance of New England forest trees will be undertaken. The data secured will deal primarily with the proportion of trees in the average stand favorable as food for the gypsy moth (Porthetria dispar L.), and will be secured by systematically sampling the entire region in New England lying mostly south of the Northern Hardwoods region; or that portion of New England known to be infested with the insect. A small strip of New York state - south to the Bronx, west to, and including most of, the Hudson River Valley and north to Glen Falls - will also be surveyed.

The system to be used in surveying this area calls for a modified checker-board pattern of sample areas. Parallel lines, 20 miles apart, running east and west and 10 miles apart, running north and south will divide the area into 180-odd sample areas - the sample areas to occur as nearly as possible at the intersections of the lines. (See accompanying map). The parallel lines will intersect in from 10 to 15% of the total number of towns in the area. Since the average town is roughly 25 square miles in area it is believed that if an area of 20.25 square miles is sampled at each intersection, this will adequately represent the area of a town. (See Fig. 1).

In each of these 20.25 square mile areas it is planned to take 200 one-fourth acre plots. This will give a total of 50 acres sampled or nearly .39% of the area involved in each sample area. These 200 sample plots will fall along 10 parallel compass lines 4.5 miles long and one half mile apart. This will give line plots at half-mile intervals along the parallel lines.

The line plots will be circular and two contiguous plots will be located at each intersection. They will be 1/4 acre each having a radius of 58.9 feet.

Field Instructions for a Forest Survey of New England

The following set of instructions are tentatively established for the use of the field personnel in collecting data relative to a study of forest types in New England. They should be carefully studied and followed as closely as possible by the various crews, for it is highly essential that the data obtained in the numerous sample plots be as nearly comparable as possible.

Crew Personnel

The personnel of the field crews will consist of a crew leader and one or two crew members. The crew leader will have immediate charge of the crew in the field. It will be his duty to see that the instructions given below are followed as closely as possible at all times. He will also be responsible for the automobile used for transportation of the crew in the field. He will sign whatever vouchers are necessary in the purchasing of supplies in case of emergencies and will be responsible for proper storage and normal upkeep of the automobile; that is, greasing, oiling, fueling etc. He will keep accurate records of the time worked by himself and crew and will report daily to headquarters at Melrose. He will report well beforehand any contemplated change of address of himself and crew. He will also be responsible for the records obtained and will dispose of them in the manner described later.

The crew members will assist the crew leader in the performance of regular duties, and will collect data as prescribed in the list of instructions given below.

Establishment of Lines

Each crew will be furnished with a list of the sample areas in the region which it is proposed to survey. These areas will be listed as towns, and by each town will be a symbol in the form of a capital letter with a sub-number. On the record forms these areas are listed as units. Thus Bronx N.Y. is Unit A 1. The center of the sample area should fall somewhere within the confines of the towns, or units, given on the attached list.

Each sample area will be in the form of a square, with an area of 20.25 square miles. The sides of the square will be 4.5 miles in length. There will be 10 parallel lines in this square, 4.5 miles in length and 1/2 mile apart. The lines will run due east and west and will be numbered from 1 to 10, from north to south, consecutively. It is absolutely essential that these lines be compass lines in order that others may locate and follow them at any future time, if necessary.

At least one of the lines in the square should be established with reference to some prominent and permanent landmark and a note of this should be entered on the record form. This landmark need not be greater than 1/4 mile from the designated line. In establishing the line with reference to the landmark the following procedure should be employed: (1) Locate and describe the landmark; (2) decide upon the direction of the identifying line and measure accurately the distance from the landmark to the line. Then from the nature of the surrounding countryside decide whether this line is to be either 1, 2, 3, 4, 5, 6, 7, 8, 9 or 10. On giving the line a number lay out a $\frac{1}{4}$ acre plot at the point and give this plot its identifying number (from 1 to 10). These notes should be placed on the record form for that plot only.

A hypothetical description, for illustration, would be as follows:

Landmark description: Barnstable Mass. Fire Tower.

Direction from landmark to line and plot: Due north. 350 yards.

Line number: 3

Plot number: 7 A

Such data will enable another to locate the line with little effort. It will show that there are two lines north and seven lines south of this particular line and will show further that there are 6 intersections on this line to the east and 3 to the west. It will obviously be up to the crew leader to determine what is or is not a permanent landmark.

Establishment of Plots

When a line has been located the crew will follow along this line by compass and establish plots at intervals of $\frac{1}{2}$ mile. Each plot will be $\frac{1}{4}$ acre in area, and circular in outline. Each circle will have a radius of 58.9 feet - roughly 20 paces. At each $\frac{1}{2}$ mile interval two contiguous $\frac{1}{4}$ acre plots will be established. The center of each of these plots will fall on the compass line followed by the crew. The two $\frac{1}{4}$ acre plots will be contiguous at the $\frac{1}{2}$ mile interval. The plots will be numbered as follows: 1 A and 1 B, 2 A and 2 B, 3 A and 3 B etc., going from east to west along the lines. If the center of the plot falls in a stand of trees the center tree, or the one nearest the center will be marked with white paint. Two parallel bands, at least 1 inch wide, will encircle the tree at breast height. These bands should be far enough apart for placing the line number and plot number between them. The line number should be above the plot number, and each number should be 4 inches tall. Thus the bands should be at least 10 inches apart on the trunk. If the trees are too small for carrying numbers the center tree should still carry the bands. On loose barked

trees a surface should be smoothed before painting. The plots should be numbered from east to west on the line, consecutively.

In traversing the lines many situations will be encountered calling for variations from this purely mechanical procedure. For instance, some lines will conceivably run their entire lengths through woodland; whereas, others will bisect both woodland and open country. Some will encounter lakes, streams and villages, and some will bisect level or rolling country while others will cross valleys and mountains. Regardless of the situations encountered the lines must be continuous and theoretically unbroken. Plots falling in farm land, pasture land, villages or lakes and ponds will be entered on the record forms as such.

On encountering a stream or lake where it is impossible to continue in a straight line it will be necessary to offset from the line a distance equal to the distance required for making a crossing. In case of streams or rivers it will be possible to mark the end of the line on one bank in such a manner that it can be seen from the opposite bank. In such instances it will be unnecessary to measure the distance of the offset, but merely to negotiate a crossing and return on the other side to a point in line with the mark on the opposite bank.

When a plot falls in a clearing in the woods not greater than 2 chains wide, and especially if the clearing is due to cutting operations, it will be advisable to make an offset from the true line, not greater than 2 chains, and establish the plot in a Lomogeneous condition. If any opening is greater than 2 chains wide the plot will be established in the open space and recorded as such. Then in the space reserved for remarks on Form 1 a brief explanation of the situation should be made. If a plot falls in swampy, impassable ground, near the edge an off set should be made, if less than 2 chains, and the plot established in a more workable situation. When an off set is made for any reason a note should be made of it giving direction and distance in the space reserved for it on Form 1,

with a brief explanation under the heading "Field Notes".

The plots should be numbered from 1 to 10 as described, from east to west. There will be a form (Form 1) for each plot and also a form for each series of plots on a line.

Collection of Field Data

Since the primary object of this survey is to determine the exact make-up of the average forest stand as to species of trees and their relative abundance, especial care must be maintained at all times to count every tree, over 2" in diameter at breast height, of every species in a plot. It will not be necessary to caliper the trees. It is expected that a very small number may be tallied that are less than 2 inches, but at the same time an equal number greater than 2 inches will not be tallied due to inaccurate estimation. Every man is expected to familiarize himself as well as possible with the common New England forest trees so as to lessen delay in determination of species. It is expected that occasions will arise when it will be practically impossible to determine trees to species. In such instances they will be listed by genera.

When the center of a plot has been determined the center tree (or the one nearest the center of the plot) will be marked as already explained. Then cords will be laid, crossing each other at the center tree and extending to the circumference of the circle. (The cords will be equal in length to the diameter of the circle). This will give four points on the circumference. With these cords in place the trees in each quadrant should be counted separately. This will simplify the work and enable the crew to count the trees with the least effort. In case any trees at or near the circumference of the circle cannot be definitely placed by estimation either inside or out of the circle, the distance from the center to the trees in question should be measured and then tallied or not according to their location.

Each crew member will be furnished with a tally register. If there are white oaks, red oaks and hickories in a plot one species will be counted at a time. For instance, all white oaks will be counted first and the total counted by each crew member will be given to the crew leader. He will total up the tallies of each member and enter on Form 1, under the code number for white oak the sum of all the counts; as white oak 45. Then another species, as red oak, will be counted and recorded, etc.

ADDITIONAL PLOT DATA

In addition to the number of trees of each species that are counted in the plots it is planned to secure additional data in the survey in order to aid in more completely determining the forest conditions of New England. The following is a list of the factors for the study of which we hope to secure quantitative data. They will be listed, with brief explanatory matter attached when necessary. Many of the desired data require no explanation.

A- Fire Damage. On entering a plot the crew leader will look over the trees and determine if any damage has resulted from fire. The presence or absence of fire damage will be entered on Form 2 by use of the following code:

1 - No indication of fire - - - - - - - - - - - - - - - - - - - 1

2 - Fire indication present but no apparent damage- - - - - - 2

3 - " " " " damage light - - - - - - - - 3

4 - " " " " " medium - - - - - - - - 4

5 - " " " " " heavy - - - - - - - - - 5

B- Site Qualities. Site qualities will be estimated by the crews as closely as possible without actually taking age and height records. It will be impossible to outline for this project a set of hard and fast rules for application in all the environments likely to be

encountered in this survey. The best that can be hoped for is a rough classification of the plots into three broad groups. These site groups will be good, fair and poor. It is understood that a good site for one species or group of species may easily, and often is, a poor site for another species, or group of species. The same applies for fair and poor sites. However, despite the chances of mistakenly identifying a site it is believed that a general picture can be drawn of the distribution and abundance of species relative to site qualities in the region, if the plots are classified into the three broad groups already mentioned.

There are four broad forest regions represented in New England according to Hawley and Hawes in Forestry in New England. They are (1) The Spruce Region, (2) The Northern Hardwoods Region, (3) The White Pine Region and (4) The Sprout Hardwoods Region.

1 - The Spruce Region - In this survey this region will be encountered in the Green Mountains of Vermont and in the higher elevations around Conway N.H. The majority of this region lies above 2500 feet elevation. Since conifers generally predominate in this region the three broad site groups will be coded as follows:

Good - Spruce slope - - - - - - - 1

Fair - Spruce flat - - - - - - - 2

Fair - Hardwoods - - - - - - - 2

Poor - Swamp - - - - - - - 3

2 - The Northern Hardwoods Region - This is a narrow belt of country lying immediately south of the spruce region and usually between 500 and 2500 feet elevation. It is characterized by an abundance of sugar maple, beech and yellow birch. It grades into the spruce region to the north and the

white pine region to the south. It extends southward into Massachusetts in the Berkshires and may be encountered in northewestern Connecticut at the higher elevations.

As hardwoods predominate here the three site groups will be coded as follows:

Good - Rich soils that may be used for farming. Excellent timber is produced. Excellent reproduction in open areas - maple predominating - 1

Fair - Hardwood swamps - black ash and soft maple abundant. Poor reproduction - 2

Poor - Soft wood swamps - - - - - - - - - - - - - - - - - - 3

3 - The White Pine Region - This is an extensive region in New England lying below 500 feet elevation. In this survey this region will be involved in Massachusetts east of the Connecticut river, in N. H. south of Lake Winnipesaukee and in Maine. It is generally characterized by sandy soils. White pine, as a whole, is the chief tree although oaks and other hardwoods are abundant. Sandy soils are best for pine and the richer soils for hardwoods. The plots in this region will be difficult to code, because of the diverse growth and the abundance of old field stands of timber growing under somewhat unnatural conditions. In general sandy soils will be listed as good (1),for pine, dark, organic upland soils fair (2),and swamps poor (3). For the oaks, dark organic upland soils will be coded as good (1), sandy soils fair (2) and swamps poor (3). Elm and red maple will be coded as follows: swamps good (1), dark upland soils fair (2) and sandy soils poor (3).

4 - Sprout Hardwoods Region - This region occupies most of Rhode Island, Connecticut and that portion of New York state involved in this survey. In this region hardwoods predominate. The oaks are abundant and the species of chestnut oak is frequent. In general the site groups will be the same as for the white pine region. Trap rock ridges will carry abundant stands of oaks; especially chestnut oak and should probably be coded as good (1). Along the coast are occasional swamps grown to southern white cedar and in such areas plots will be coded as good (1) if southern white cedar prevails.

It is hoped that the above broad discussions will aid the crews in generally labeling the plots according to site; and it is expected that it would be impracticable to spend excessive time in more closely identifying the sites.

C - Exposure. The exposure of the plots will be coded on Form 2 as follows:

Northern	1
Eastern	2
Southern	3
Western	4

D - Topographic Descriptions. Notes on the topography of the plots will be estimated and coded on Form 2 as follows:

Slope 0 to 15%	1
" 16 to 30%	2
" 31 to 60%	3
" over 60%	4
Ridge top	5
Bottomland	6

E - Forest Conditions. The forest conditions to be recognized and coded on Form 2 are as follows:

Old growth uncut - - - - - - - - - - 1

" " partly cut - - - - - - - 2

Second " uncut - - - - - - - - - 3

" " partly cut - - - - - - - 4

Clear cut - - - - - - - - - - - - - - 5

Reproduction - on new land, old fields etc. - - - - - - - - - - - - - 6

Non-commodity and protection forests - - - - - - - - - - - - - - - - 7

Old field stands - - - - - - - - - - 8

F - Reproduction Record - Reproductions less than 2 inches D B H will be coded on Form 2 as follows:

Complete - 75 to 100% area occupied - - - - - - 1

Partial - 25 to 75% " " - - - - - - 2

Scanty - 5 to 25% " " - - - - - - 3

None - less than 5% " - - - - - - 4

G - Vigor of Dominant Species - The apparent vigor of the dominant trees in the plots will be coded as follows:

Good - in healthy condition - - - - - - - - - 1

Fair - stunted; unhealthy looking foliage - 2

Poor - decadent - dead tops- few live branches - - - - - - - - - - - - - - - - 3

H - Species of Reproduction -Observe and record in the order of their numerical prevalence the three most numerous species in the reproduction, using their species group code number. Record on Form 1.

Additional Studies

In surveying the region represented in this forest type survey exceptional opportunities for observing and recording the distribution and abundance of certain prominent forest insects will be afforded. The crews are advised to be constantly on the alert while in the various plots for the presence of any of the following insects: beech scale, balsam wooly aphid, European pine shoot moth and the spruce sawfly. When any plot contains beech the trunks, especially near the base, of the trees should be examined for the beech scale. When the plots contain white or red pine the tips of the leaves and branches should be examined for the pine shoot moth. When balsam is present in a plot they should be examined for balsam wooly aphid; and when spruce is present the foliage should be surveyed for defoliation by the spruce sawfly. In case any of these insects are discovered the crew leader should collect a sample and mail it to the Melrose Highlands Station for identification. Each crew will be supplied with a series of blanks and one will be filled out by the crew leader giving the information asked for on the blank when any infestation is discovered. Especial care should be taken in filling out the portion devoted to location, since it may often be desired to visit the plots again for further study of the insects.

If any gypsy moth egg clusters are noted in the plots a record should be made of it under "Field Notes" on Form 1. This will also apply to defoliation by gypsy moth larvae.

Care of Records

The crew leader will be responsible for the records. Since it is probable that a crew will complete a line of plots a day it is suggested that the records be mailed in each day. They will be sent by registered mail and the crew leader will keep his receipts until he obtains confirmation from the station of their

safe arrival. If none are mailed in any day a note should be made of it on the daily time cards, under remarks, that will be mailed to the station each day.

List of Species of Forest Trees likely to be Encountered in the Survey and the Code Numbers for use in Recording Them

CODE NO.	SPECIES	CODE NO.	SPECIES	CODE NO.	SPECIES
1	White Oak	21	White Ash	41	Fire Cherry
2	Red "	22	Black Locust	42	White Spruce
3	Black "	23	Sycamore	43	Black Spruce
4	Scarlet Oak	24	Red Cedar	44	Flowering Degwood
5	Chestnut "	25	So.White Cedar	45	Mountain Maple
6	Bur "	26	Sassafras	46	Striped Maple
7	Post "	27	Shagbark Hickory	47	Tulip
8	Scrub "	28	Bitternut "	48	Butternut
9	Swamp White Oak	29	Mockernut "	49	Balsam Fir
10	Gray Birch	30	Pig nut "	50	Scotch Pine
11	Paper "	31	Red Spruce	51	Jack Pine
12	Beech	32	Hemlock	52	Norway Spruce
13	Willow	33	Tamarack	53	Boxelder
14	White Pine	34	Red Pine	54	Mountain Ash
15	Pitch Pine	35	Basswood	55	Blue Beech
16	Am. Elm	36	L.T. Aspen	56	Black Birch
17	Tupelo	37	P. tremuloides	57	Yellow Birch
18	Hop Hornbeam	38	Slippery Elm	58	River Birch
19	Red Maple	39	Black Cherry	59	Red Ash
20	Sugar Maple	40	Choke "	60	Honey Locust

In case any additional species of tree are encountered they will be added and given numbers as they occur.

FOREST TYPE SURVEY FORM NO. 1

Date

Crew Lead.

Crew Mem.

Crew Mem.

Forest Cond.

Fire Damage

Reprod. Data

Distrib. (Code)

3 Prevail.Sp.(Code No.)

State

County

Unit

Line No.

Plot No.

Off Set

Bearing

Distance (ft.)

Tree Tallies - Species of Tree represented by Symbol

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
46	47	48	49	50	51	52	53	54	55	56	57	58	59	60

Field Notes

FOREST TYPE SURVEY FORM NO. 2

Code Index	
Fire Damage	
None	1
Present, no damage	2
" light "	3
" heavy "	4
Site Index	
Good	1
Fair	2
Poor	3
Exposure	
Northern	1
Eastern	2
Southern	3
Western	4
Forest Conditions	
Old growth uncut	1
" " partly cut	2
2nd growth uncut	3
" " partly cut	4
Clearcut	5
Reproduction	6
Non-Com.forests	7
Fire killed	8
Old field stands	9
Reproduction Rec.	
Complete	1
Partial	2
Scanty	3
None	4
Vigor Dom. Sp.	
Good	1
Fair	2
Poor	3

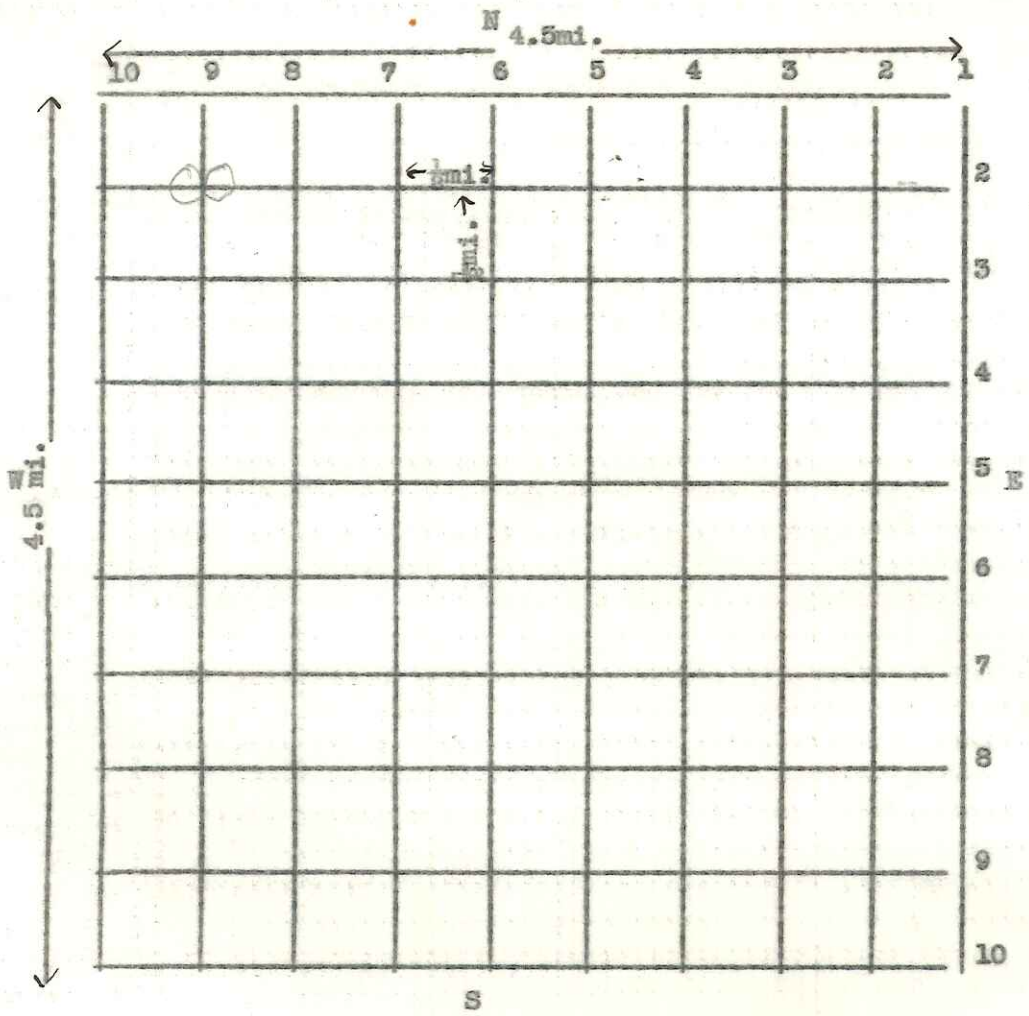
Line No. State Unit Date

Crew Leader Crew Members

Plot No.		Fire Damage	Site Index	Exposure	Topog. Desc.	For. Cond.	Rep. Rec.	Vig. Dom. Sp.	Remarks
1	A								
	B								
2	A								
	B								
3	A								
	B								
4	A								
	B								
5	A								
	B								
6	A								
	B								
7	A								
	B								
8	A								
	B								
9	A								
	B								
10	A								
	B								

Topog. Desc.	
Slope 0 to 15%	1
" 16 to 30%	2
" 31 to 60%	3
" over 60%	4
Ridge top land	5
Bottom land	6

FIG. 1



MEMORANDUM CONCERNING THE GIPSY MOTH PROBLEM

The gypsy moth project has for its purpose the prevention of spread of this insect and the clean up and extermination of outlying areas of infestation. It is carried on by the Federal Department of Agriculture in cooperation with the States where infestation exists.

The gypsy moth is a pest of prime importance and inflicts heavy damage to forest, shade and fruit trees in the infested area in New England.

There are many factors which are favorable to prevention of the spread of this insect. The more important of these are:

1. The female moth does not fly and therefore the spread of the insect is restricted by this natural limitation.

2. The prevailing winds in the northeastern part of the United States, where the gypsy moth is present, are usually favorable to prevention of spread to uninfested regions.

3. Many isolated infestations have been successfully eradicated, some of them covering several hundred square miles.

4. It has been demonstrated that the methods of scouting and control used in combating the gypsy moth are effective and practicable.

5. There exist at the present time well organized Federal, State and local agencies with trained personnel who are familiar with the area infested and with methods of control.

The gypsy moth is present in all of the New England States. There is an infestation on Long Island in the vicinity of Roslyn, New York, and one in the Bronx section of New York City. These infestations are in process of eradication by the Conservation Department of the State of New York. An infestation in northern New Jersey covering more than 400 square miles which required intensive work over about five times that area has been cleaned up although a small area still requires additional work. The New Jersey Depart-

ment of Agriculture actively cooperated in this work. An isolated infestation also occurs in northeastern Pennsylvania near Wilkes Barre, covering an area of approximately 470 square miles. This work is carried on cooperatively between the Federal Department of Agriculture and the Pennsylvania Department of Agriculture and Department of Forests and Waters.

In New England the work is organized on the basis of the States handling the control work throughout their territory except in an area known as the barrier zone which is conducted cooperatively by the Federal Department of Agriculture and the Department of Conservation of the State of New York.

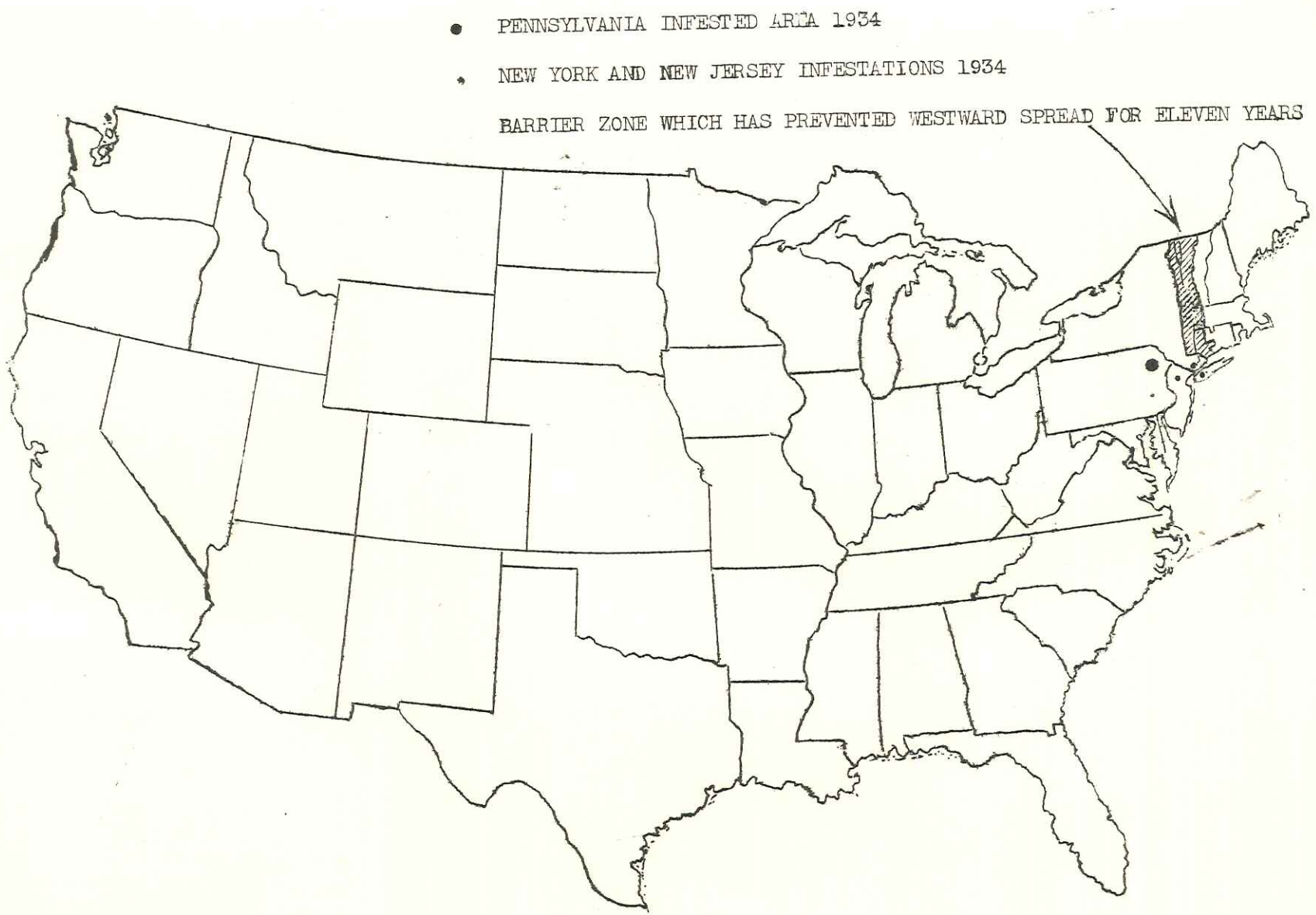
The barrier zone was established in 1923, and embraces an area of approximately 25 miles in width east of the Hudson River, and extending from Long Island Sound to the Canadian border. About half of this area is in New York State and the balance is in western Vermont, Massachusetts and Connecticut. It is the shortest line that can be selected for preventing westward spread of the insect, and the topography is more favorable than in most of the territory either east or west of this line. Prior to the establishment of this zone the average westward spread was from five to six miles a year. Since the zone was established more than 11 years ago, westward spread has been prevented and 400 infested areas have been cleaned up and the moth exterminated. If the work had not been done these areas would now be heavily infested centers each of which would cost thousands of dollars to clean up, and from which there would have been constant spread of the insect.

The gypsy moth was more abundant than usual in the territory east of the Connecticut River in the New England States during the past year and defoliation was abnormally heavy. At the present time there are unusual numbers of overwintering egg clusters, fore-

casting heavy defoliation next summer and conditions favorable for the spread of this pest. It is necessary, in order to hold the insect in control and reduce the outlying areas, that this work be pushed vigorously. Failure to do this will make possible the westward spread of the insect and a gradual building up of infestation so that the pest will soon get beyond control.

For many years the States concerned have expended more funds than have been appropriated by the Federal Government, and during the last few years State expenditures have averaged over $1,000,000 annually, most of this money being expended on shade trees and trees on public grounds and about private residences, because widespread treatment of forests over large areas has not been possible except in cases where the expenditure was justified on the basis of preventing spread of the pest to other territory. If it should become widely established throughout the United States, it is certain that many times the sums now expended by all agencies will be necessary to protect the tree growth or an even greater loss will result from the loss of the trees themselves.

The accompanying map indicates the barrier zone and the isolated infestations beyond the zone which require treatment. They are so located that failure to do the necessary work will furnish abundant opportunity for the insect to spread rapidly throughout eastern United States and eventually to the south and west.


PENNSYLVANIA INFESTED AREA 1934
NEW YORK AND NEW JERSEY INFESTATIONS 1934
BARRIER ZONE WHICH HAS PREVENTED WESTWARD SPREAD FOR ELEVEN YEARS

HARVARD FOREST RECORDS

EXPERIMENTAL PLOTS

Block _____
Compt. _____
Stand See exact location below.
Map of _____

Co- Experiment No. 35-1
Plot No. _____
Date June & July 1935
By W.L. Baker, A.C. Cline et al.

Title of Experiment: Gypsy moth population eruption.

Purpose: (1) To study the reactions of the insects to its food supply in an area never before heavily defoliated, in order to determine whether it had increased to outbreak numbers irrespective of food plants, or only in concentrations of

Exact Location: (Sketch attached? Yes) (over)

The entire township of Petersham was surveyed from several high vantage points to locate all defoliated areas.

General Plan of the Experiment: (Detailed plan attached? Yes) Observations of the degree of defoliation caused by gypsy moth larvae were made by forest types to give the distribution of the insect. Selected colonies were analysed to obtain the relationship between the proportions of favored and unfavored food species and amount of defoliation. Similar distribution surveys are to be made periodically from the same vantage points.

General Description of Conditions at Time of First Treatment or Measurement: (Detailed record attached? No) (Use Detailed Record Form) Over three quarters of the area of Petersham had been cut over white pine land. This has been regenerated to mixed hardwood stands, in which red oak predominates. However, red oak rarely occurs in pure stands, and the assumption is that the forests have gradually been changed into ones containing a constantly increasing proportion of favored food species,

General Method of Treatment or Measurement: (Detailed statement attached? Yes) (Use Detailed Record Form)

The defoliated areas were located from prominent open places, binoculars being used to make certain that only such areas were noted. During the course of travel on survey constant watch was kept for larvae. The defoliated stands were visited, and the composition and percentage defoliation of all tree species were determined by ocular estimate. The composition of the margins of adjoining stands was also recorded for comparison with the defoliated areas.

Plot History

Number	Date and Kind of Treatment or Measurement			Record Completed and Attached	
1st	1935	Reconnaissance	(date)	Fall 1935	8/12/40
2nd	1936	Reconnaissance			
3rd					
4th					

Outcome of Experiment and Conclusions: (Full statement attached? Yes) Results showed that heavily defoliated areas were invariably concentrations of the favored host species of all larval instars. Complete defoliation was not observed where favored hosts constituted less than fifty percent of the stand. A program for the control of gypsy moth outbreaks by means of the adjustment of stand composition has been devised. Seven types of stand where recognized and specific treatments suggested.

Purpose (cont'd): favored food; and (2) to determine to what extent any discriminating food habits of the insect that might be discovered would permit the application of silvicultural measures of control in a particular locality.

Co-Op. No. 35-1
Plot No. —

Baker, MacAlvey + Olive

82 stands

Gypsy Moth Study

Petersham
June 1935

	C.B.		Pop.		R.O.		W.O.		Apple		R.M.		B.C.		P.B.		B.B.		W.A.		P.C.		Butternut	Elm	H.M.	Hick.	W. Pine	
					X		X		√		X√		X		√		√		√									
1	15	4/4	75	4/4							3	1/4	2	3/4													5	1/8
2	45	4/4	45	4/4	1	3/4			1	4/4	1	2/4	2	1/4					1	0/4	1	1/4					1	1/4-7/8
3	20	3/4	75	7/8	1	2/4					2	1/4							1	0/4	1	1/4						
4	5	3/4	60	4/4	2	4/4 4/4	1	3/4-4/4	1	3/4	1	1/4	1	1/4	3	1/2	5	1/4-1/2			1	1/4					20	2/4 7/8
5	75	4/4	2	4/4	10	7/8-4/4	5	3/4-4/4			2	1/8-2/4	1	1/4					1	0/4			1	1/8			1	4/4-4/4
6	35	7/8	30	3/4-4/4	15	3/4-4/4			1	4/4	1	1/4	1	1/4					1	0/4	5	1/4					5	1/8-3/4
7	90	4/4			2	4/4	3	4/4			3	1/4-1/2															1	0/4-2/4
8	90	4/4	1	4/4							1	0/4-1/8	1	0/4							1	0/4					5	1/4-3/4
9	45	4/4	25	4/4	1	2/4-3/4	5	4/4			1	2/4			5	3/4			1	0/4				1	1/8		15	2/4-4/4
10	60	7/8-4/4	35	4/4			1	4/4	1	4/4	1	1/4	1	1/4							1	1/4-2/4						
11	40	4/4	20	4/4	5	3/4-4/4	1	3/4 4/4			4	1/4-3/4	1	1/4	30	1/4-3/4	1	2/4			1	1/4-3/4					4	1/8-4/4
12	10	3/4	60	4/4	1	4/4					20	1/4	2	2/4					1	0/4	1	3/4		3	1/8		2	3/4
13	3	4/4									1	1/4															1	3/8
14	5	4/4	5	4/4	45	4/4			10	4/4	15	2/4	15	1/4-3/4					1	1/8							3	3/4-4/4
15	10	4/4	15	4/4	30	3/4 4/4	25	4/4			2	1/8-2/4									1	1/4			3	7/8	2	2/4
16	60	7/8	25	4/4					1	4/4	2	2/4	2	1/4					4	0/4	4	3/4		2	2/4		3	7/8
17	10	3/4-4/4			40	3/4-4/4	40	7/8-4/4			5	1/8-1/4	1	1/4	1	2/4 4/4											1	3/4
18	80	4/4	15	4/4	2	4/4					2	1/4			1	3/4												
19	80	4/4			1	3/4	1	7/8			3	3/4															15	1/4-4/4
20	80	4/4	5	4/4	2	3/4							2	1/4					2	0/4							5	2/4
21	100	4/4																										

	C.B.		Pop.		R.O.		W.O.		Apple		R.M.		B.C.		P.B.		B.B.		W.A.		P.C.		Butternut		Elm		H.M.		Hick		W.P.	
22	98	3/4	2	4/4																												
23	90	7/8	5	4/4	1	4/4					1	2/4							1	0/4											2	7/8-4/4
24a	65	4/4	25	4/4							2	1/4	2	3/4											3	1/4					3	2/4
24b	80	4/4	5	4/4	1	2/4					3	1/4	1	3/4	2	2/4	1	2/4	1	0/4											5	1/4-4/4
24c	70	4/4	50	4/4	3	4/4					1	2/4	3	2/4	3	1/4					10	3/4-3/4									10	4/4-4/4
24d	85	4/4	1	4/4	1	4/4					5	1/4					5	7/8			1	1/4					1	1/4			1	4/4
25	30	7/8-4/4	25	4/4	1	4/4	1	4/4	1	4/4	1	1/8							1	0/4	1	1/4	1	0/4	1	1/4	1	1/8-1/4	1	1/4	35	3/4-4/4
26					35	2/4-7/8	45	7/8-4/4			10	1/4-2/4			1	3/4-4/4	3	2/4-7/8	1	0/4			1	0/4					1	7/8	2	0/4-7/8
27	45	3/4-4/4	10	3/4-4/4	20	7/8-4/4					5	2/4-7/8							2	0/4	1	2/4							2	1/4-7/8	15	3/4-4/4
28	45	4/4	20	4/4	10	7/8					10	1/8													1	1/4			1	1/4	1	4/4
29	75	4/4	2	4/4	10	7/8-4/4	2	4/4	1	4/4			2	1/4			2	3/4	1	0/4											2	3/4-7/8
30a	90	7/8									1	4/4	1	2/4					1	0/4	1	2/4	1	0/4			1	1/4			4	3/4
30b	40	4/4	35	4/4	10	7/8-4/4			1	4/4	1	2/4	5	2/4							1	2/4					2	2/4				
31	40	4/4	5	4/4	10	7/8-4/4	4	4/4	4	4/4	2	2/4	4	4/4			2	7/8	5	0/4							1	2/4			15	0/4-4/4
32	20	7/8	10	4/4	15	3/4	15	3/4			5	1/4	5	2/4					10	0/4									10	1/8-1/4	10	3/4
33	70	3/4	20	7/8	5	3/4					2	1/8			1	1/4					1	2/4			1	0/4						
☆34	30	2/4	15	4/4	12	7/8							1	2/4																	40	1/4-4/4
35	1	3/4	1	4/4					2	4/4							1	2/4	1	0/4	1	2/4			1	1/8					2	1/4-3/4
36	15	7/8-4/4	1	4/4	30	3/4-4/4	30	7/8-4/4			20	1/4-2/4			1	2/4-7/8	1	3/4-7/8													1	2/4
37	50	4/4	40	4/4							3	1/8																			7	3/4-4/4
38	15	4/4	1	4/4	35	4/4	40	4/4			2	1/4-2/4	1	1/8	1	4/4	1	4/4													1	2/4-4/4

	C.B.			Pop.		R.O.			W.O.			Apple		R.M.		B.C.		P.B.		B.B.		W.A.		P.C.		Butternut	Elm	A.M.		Hick		W.P.		
39	95		4/4																												3		4/4
40	75		4/4	20		1/4	1		4/4					1	3/4	1	2/4														1		4/4
41a	75		7/8-4/4	2		4/4						2	4/4			2	1/4														15		2/4-4/4
41b	87		4/4				4		2/4-4/4					3	1/4							1	0/4								5		2/4-4/4
42	70		4/4	20		7/8								2	1/8	1	1/8					1	0/4	1	1/4						5		1/4-7/8
43	30		7/8-4/4	10		4/4	10		3/4-4/4	20		3/4-4/4		15	1/4-2/4			1		3/4	1	7/8	1	0/4				1		4/4	1		2/4
44	5		3/4	65		4/4	5		1/4-7/8	15		3/4-3/4		5	1/8-1/4								1	0/4							2		1/4-2/4
45							50		3/4-4/4	2		3/4-4/4		20	1/8-1/4			20		3/4-4/4	5	7/8	1	0/4									
46	80		7/8	2		4/4						1	4/4															2	1/8		15		1/4-4/4
47	90		4/4	2		4/4						1	4/4	2	1/8			1		1/8		2	0/4								1		2/4
48	70		4/4				1		7/8					5	1/8						1	2/4	1	0/4	15	1/8		1		0/4		5		2/4
49	45		4/4	45		4/4								2	3/4	1	1/4-2/4										1		1/4		5		3/4
50	75		4/4											15	1/4							1	1/4				1		1/4		2		3/4-7/8
51	10		4/4	80		4/4	1		4/4					2	1/4	1	2/4							1	2/4						5		4/4
52a	2		4/4	80		7/8-4/4	2		2/4-7/8			1	4/4			1	0/4					2	0/4			1	0/4					10		0/4-3/4
52b				60		4/4	2		3/4					2	1/8	2	0/4	1		7/8		1	0/4	2	0/4						30		0/4-2/4
53	10		2/4	70		3/4-4/4	2		1/4-2/4	1		3/4		3	1/8						5	1/8-3/4	1	0/4					1		1/8	5		0/4-1/4
54				30		4/4	30		3/4-4/4					10	1/8	10	1/8					5	0/4					2	0/4	1	1/8	1	0/4	10	1/4-4/4
55							50		7/8	40		7/8		1	1/8						1	1/8-2/4	1	0/4							1	2/4	5		0/4-3/4
56a	40		4/4	40		7/8-4/4	2		7/8-4/4	3		7/8-4/4	1	4/4	3	0/4-1/8	3	3/4		0/4													5		1/4-7/8
56b	5		3/4-4/4	40		7/8-4/4	1		2/4	1		2/4		35	1/8	1	1/8	2		3/4	5	1/8-7/8											10		2/4-4/4

	G.B.		Pop.		R.O.		W.O.		Apple		R.M.		B.C.		P.B.		B.B.		W.A.		P.C.		Butternut		Elm		H.M.		Hick		W.P.	
57	35	4/4			20	3/4-4/4	2	4/4			30	1/4-3/4	2	1/4							2	2/4									5	1/4
58	80	4/4	10	4/4	2	4/4			1	4/4	1	2/4			3	3/4			1	1/8					1	2/4						
59	40	4/4	10	4/4	30	7/8-4/4			3	4/4	10	1/8	5	1/4									2	1/8								
60	85	4/4			5	3/4-4/4			3	4/4			1	1/4					1	0/4											5	3/4-3/4
61	40	4/4	1	4/4	1	3/4-4/4			1	4/4			1	1/4-3/4									1	0/4	8	0/4					5	1/8
62	90	7/8							1	4/4	1	1/8							1	0/4-1/8	5	1/4					1	1/4				
63	70	4/4	5	4/4	3	3/4-4/4					4	1/4	2	3/4					1	0/4	1	2/4					5	→ 1/8			10	3/4-4/4
64a			100	7/8-4/4																												
64b			100	0/4-4/4																												
65	40	4/4			15	7/8-4/4	25	4/4			10	1/8-1/4							1	0/4	1	3/4-3/4									3	4/4
66	80	7/8-4/4	15	7/8-4/4							1	1/8									1	1/4									3	1/8-3/4
67	1																															
68	10	7/8-4/4	25	4/4			45	3/4-4/4			1	7/8	15	1/4													1	1/8	1	7/8		
69	80	4/4			5	3/4-7/8	5	7/8			1	1/4							1	0/4	1	1/8					1	1/8-7/8	3	1/4-4/4		
70	5	2/4	5	4/4	25	3/4-4/4	30	3/4-4/4			5	2/4					3	7/8	1	0/4					1	0/4	5	3/4-4/4	20	1/4-4/4		
71			2	4/4	45	4/4	35	4/4			5	2/4	2	2/4							2	2/4					3	1/8-7/8	4	3/4-7/8		
72	85	7/8							1	4/4	1	1/4					2	1/4-3/4	1	0/4					1	1/8			7	3/4		
73	60	7/8	2	4/4	1	3/4-7/8					10	1/4-3/4							1	0/4									15	3/4-7/8		
74	1	4/4			25	4/4	40	4/4			5	1/4-3/4					5	3/4-4/4	1	0/4							5	7/8	15	2/4-4/4		

	Dogwood		Thorn Apple		Hazelnut			Chestnut			Alder		Willow			Hemlock	Y. B.	Sumac	Witch Hazel	Area
1																				.5
2	1	0/4	1	0/4																1.0
3																				.5
4																				.25
5					1	3/4	4/4	1	2/4											4.00
6	1	0/4									4	4/4	1	4/4						2.0
7			1	4/4																3.0
8													1	4/4						1.0
9											1	7/8								2.0
10																				2.0
11								1	1/4							1	1/8	1	1/4	3.0
12																				.5
13											95	4/4								.25
14								1	3/4											1.0
15								1	2/4	10	4/4							1	0/4	2.0
16																				2.0
17								1	1/4-3/4									1	4/4	10.0
18																				1.0
19																				3.0
20											2	3/4								.25
21																				1.0

	Dogwood	Thorn Apple	Hazelnut	Chestnut	Alder	Willow.	Hemlock	Y.B.	Sumac	Witch Hazel	Beech	Amelanch.	Black Gum	P. Pine		
22																1.5
23																.5
24a																.5
24b					1 7/8											1.0
24c																2.0
24d																.5
25																2.0
26										1 4/4						10.0
27																1.0
28					10 4/4				2 0/4							1.0
29					2 4/4						1 4/4					.5
30a																2.0
30b	1 0/4	1 4/4							2 0/4			1 4/4				2.0
31									2 0/4			5 4/4	1 2/4			1.0
32																1.0
33																.5
34													2 0/4			2.0
35					90 4/4											.5
36		1 3/4-3/4														50.0
37																.5
38		1 1/4				1 1/4							1 3/4-3/4			15.0

	Dogwood	Thorn Apple	Hazelnut	Chestnut	Alder	Willow	Hemlock	Y.B.	Sumac	Witch Hazel	Beech	Americ.	Black Gum	P. Pine	Basswood	
39							1 4/4							1 4/4		5.0
40												1 4/4				5.0
41a																2.0
41b																20.0
42																4.0
43				1 1/4						4 7/8						5.0
44				1 1/4 3/4				1 0/4								2.5
45	1 0/4											1 4/4				10.0
46																2.0
47						1 7/8										1.0
48							1 1/8									1.0
49						1 4/4										10.0
50					5 4/4									1 4/4		1.0
51																3.0
52a				1 1/8												1.0
52b																3.0
53				1 1/4			1 0/4									.25
54											1 4/4					.5
55							1 0/4									1.0
56a		1 4/4	1 2/4									1 4/4				15.0
56b							1 0/4									2.0

	Dogwood	Thorn Apple	Hazelnut	Chestnut	Alder	Willow	Hemlock	Y. B.	Sumac	Witch Hazel	Beech	Amel.	Black Gum	P. P.	Basswood	
57				2 2/4			2 1/8									.5
58																1.0
59																.5
60																1.0
61					40 2/4-4/4							1 2/4				.75
62	1 1/8															1.0
63																1.0
64a																.5
64b																.25
65				1 2/4			1 3/4-7/8				2 4/4			1 2/4		.5
66																2.0
67																
68				1 1/8								1 4/4				.25
69	1 4/4			1 2/4										1 1/4		3.0
70												1 4/4				1.0
71				1 2/4												.5
72					1 3/4-4/4			1 1/4-3/4								1.0
73		1 2/4														.5
74				1 2/4			1 4/4							1 2/4		5.0

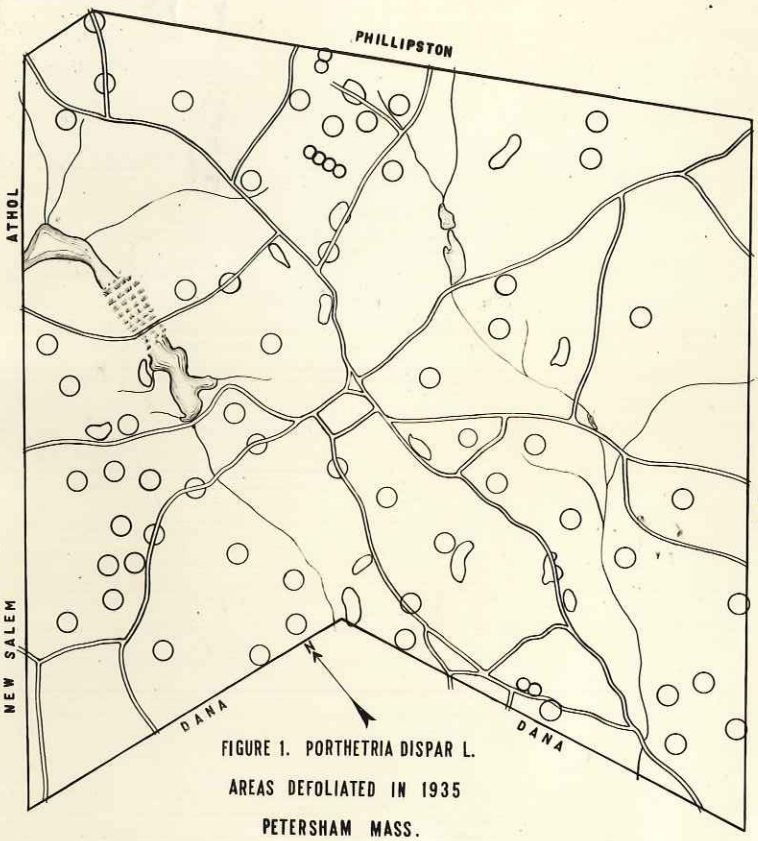
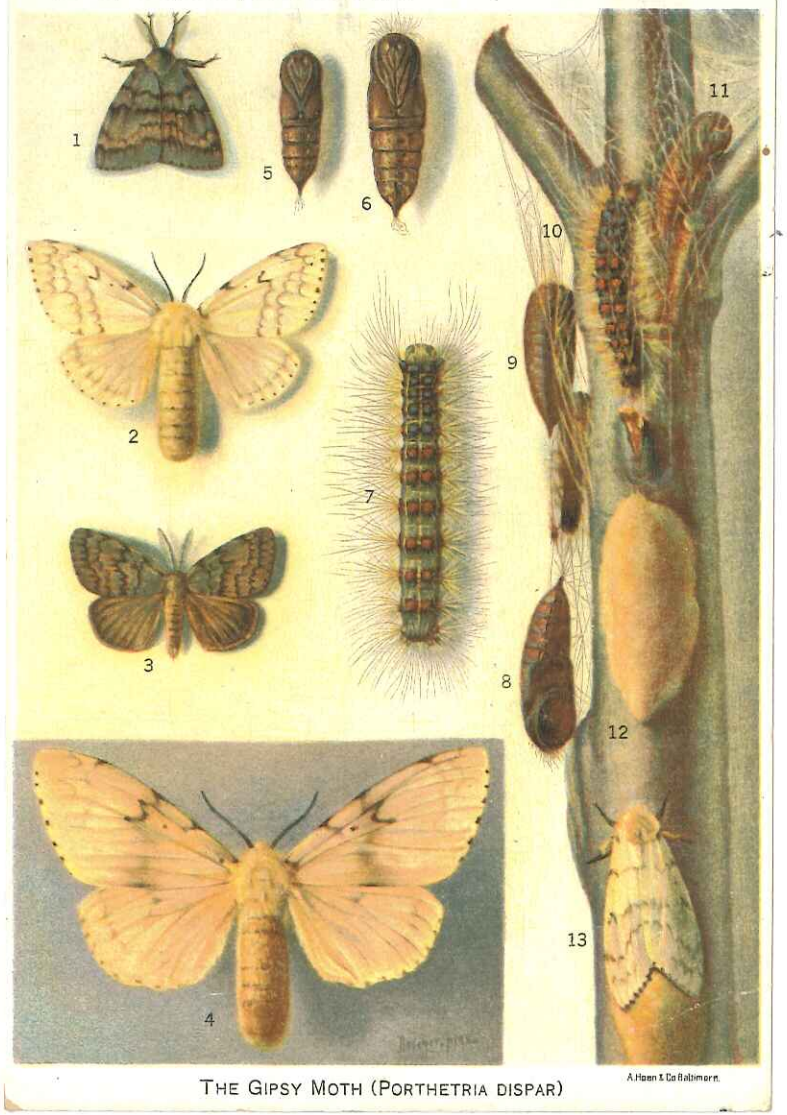


FIGURE 1. PORTHETRIA DISPAR L.
AREAS DEFOLIATED IN 1935
PETERSHAM MASS.

Co-Exp. No. 35-1
Plot No. ——

U. S. Dept. of Agriculture, Bureau of Entomology



THE GIPSY MOTH (PORTHETRIA DISPAR)

A. Hoen & Co. Baltimore.

BUREAU OF ENTOMOLOGY

THE GIPSY MOTH

(*Porthetria dispar* L.)

[SLIGHTLY LESS THAN NATURAL SIZE]

The various stages in the life history of the Gipsy Moth are shown on the reverse side of this card. Figs. 12 and 13 show the egg clusters. These may be found on trees and fences, in stone walls and in rubbish heaps from July until the following May. During the first continued warm weather in the spring the caterpillars emerge and feed on the new foliage of most deciduous trees and shrubs. The majority of the caterpillars (fig. 7) become full grown by the middle of July and choose some hidden or secluded spot for pupation (fig. 10), such as the underside of limbs of trees, in stone walls and in brush or rubbish upon the ground. About nine days are spent in the pupa stage (figs. 5, 6, 8, 9, 11). The female moth (figs. 2, 4) does not fly, but begins to deposit a mass of eggs (fig. 13) near the pupal case from which it emerged, covering the eggs with the fine hairs from its ab n. These masses contain on an average 400 eggs. The male moth (figs. 1, 3) flies freely, but dies soon after mating.

The most effective treatment for controlling this insect is by saturating the egg masses with creosote or by spraying the foliage when the caterpillars are small. Ten pounds of arsenate of lead paste or five pounds of powder should be used to each 100 gallons of water. The trunks of the trees can also be banded with burlap, tanglefoot, or other suitable banding material, and the caterpillars which gather beneath the bands killed with a knife or crushed with a stiff wire brush. Much good can be accomplished in woodland by removing the most favored food plants of this insect

U. S. DEPARTMENT OF AGRICULTURE

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PENALTY FOR PRIVATE USE, $300

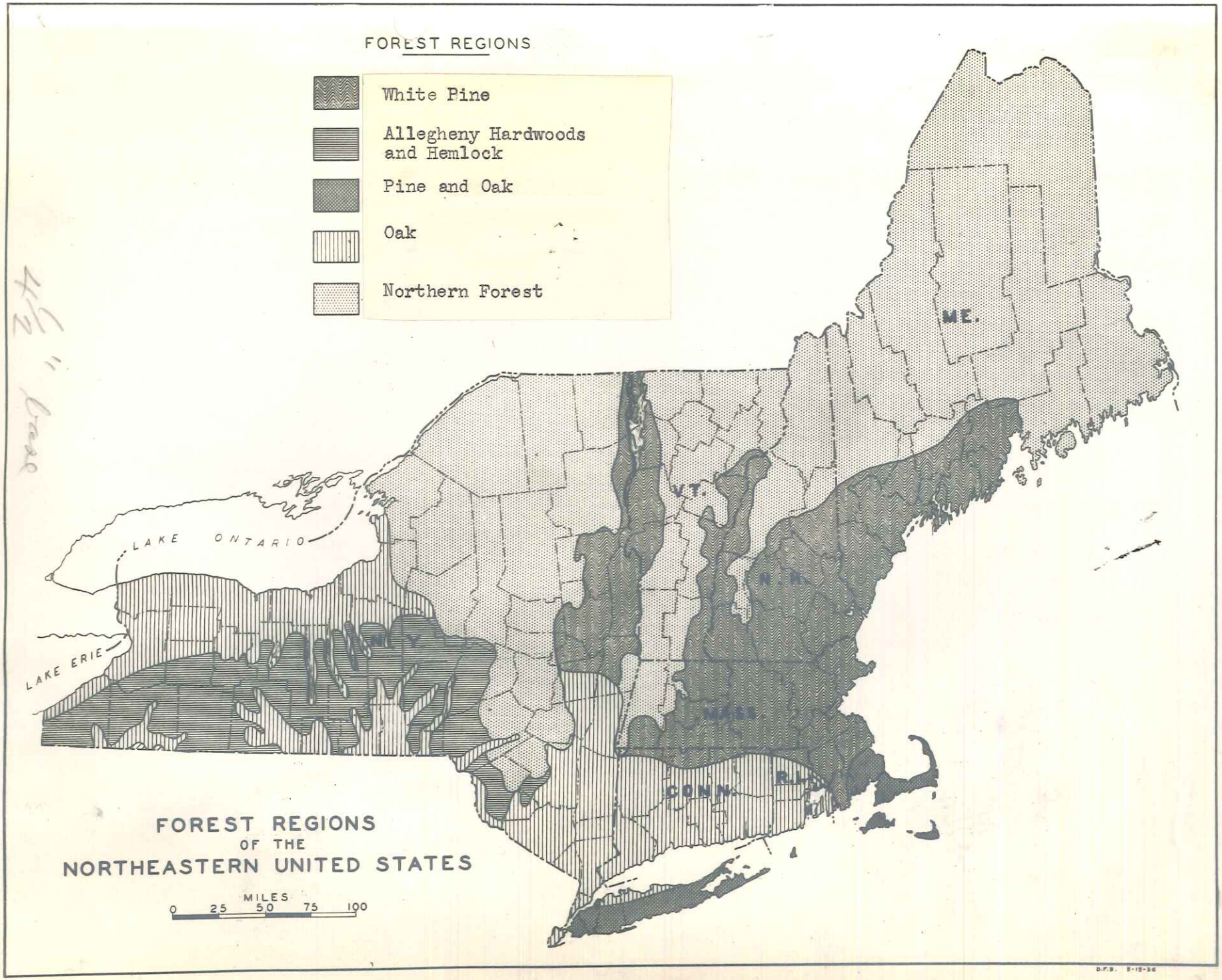
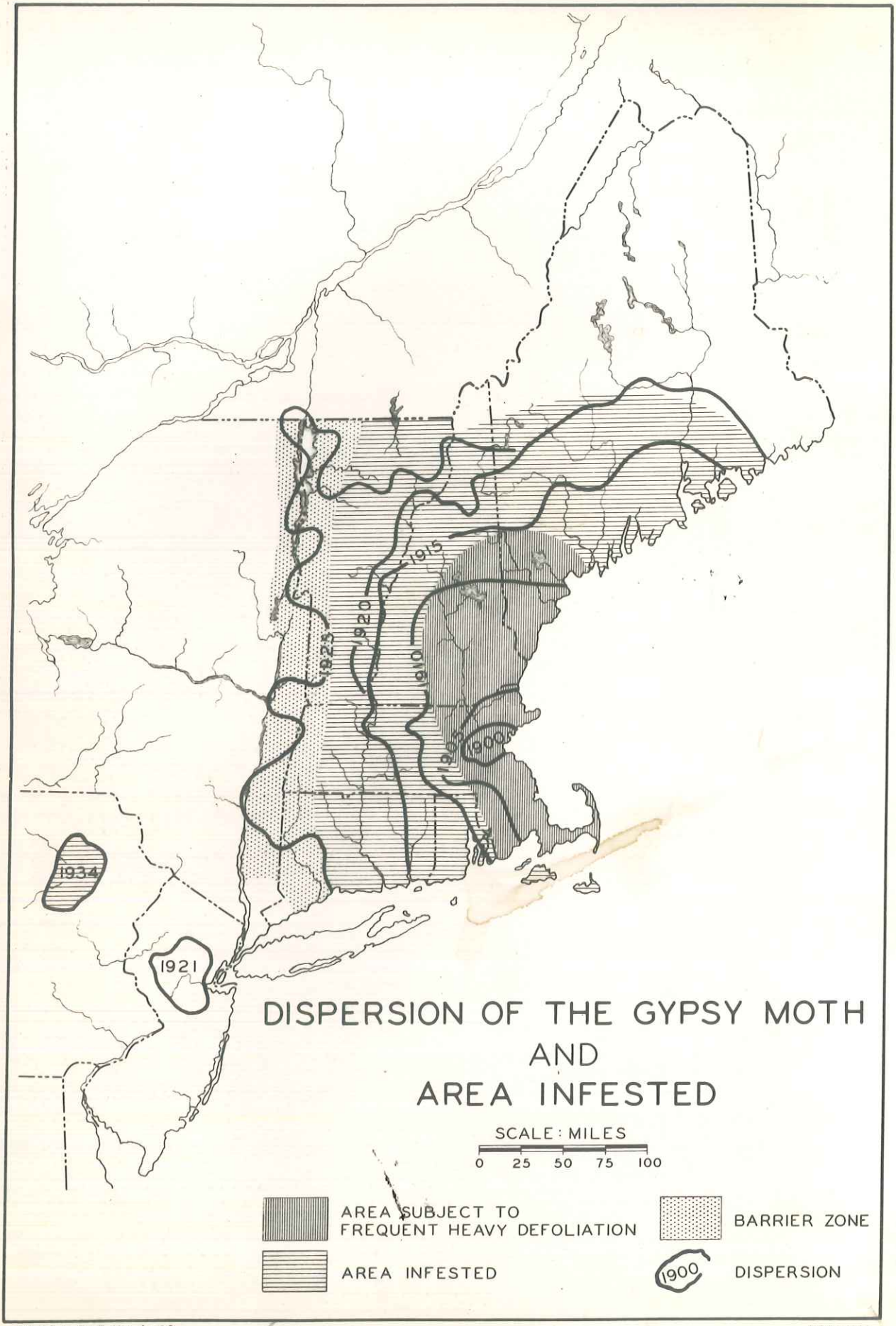

FOREST REGIONS
White Pine
Allegheny Hardwoods and Hemlock
Pine and Oak
Oak
Northern Forest
ME.
VT.
N.H.
MASS.
CONN.
R.I.
LAKE ONTARIO
LAKE ERIE
FOREST REGIONS
OF THE
NORTHEASTERN UNITED STATES
MILES
0 25 50 75 100

Figure 3.

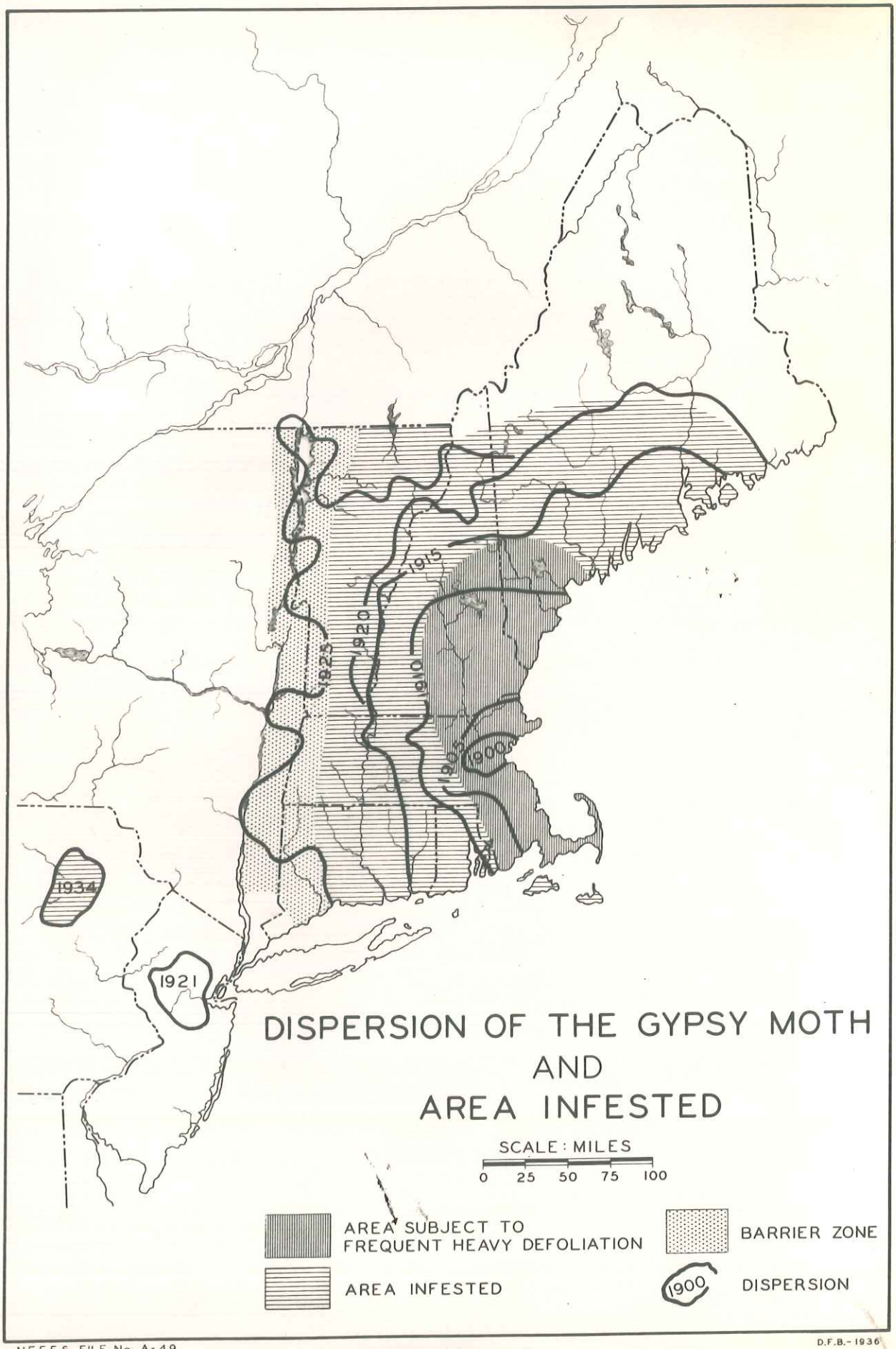


N.E.F.E.S. FILE No. A-49

D.F.B.-1936

4½" base

Figure 1

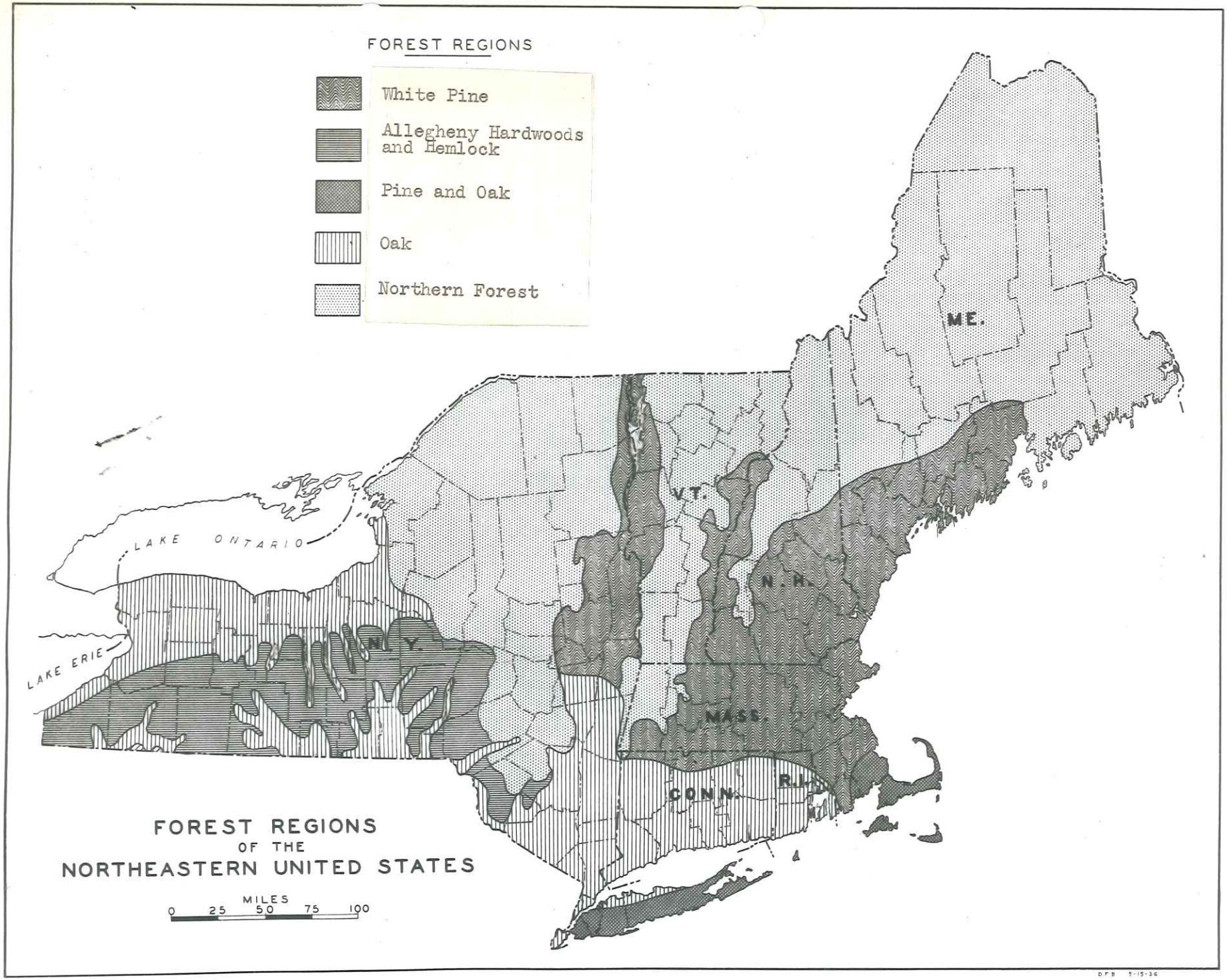


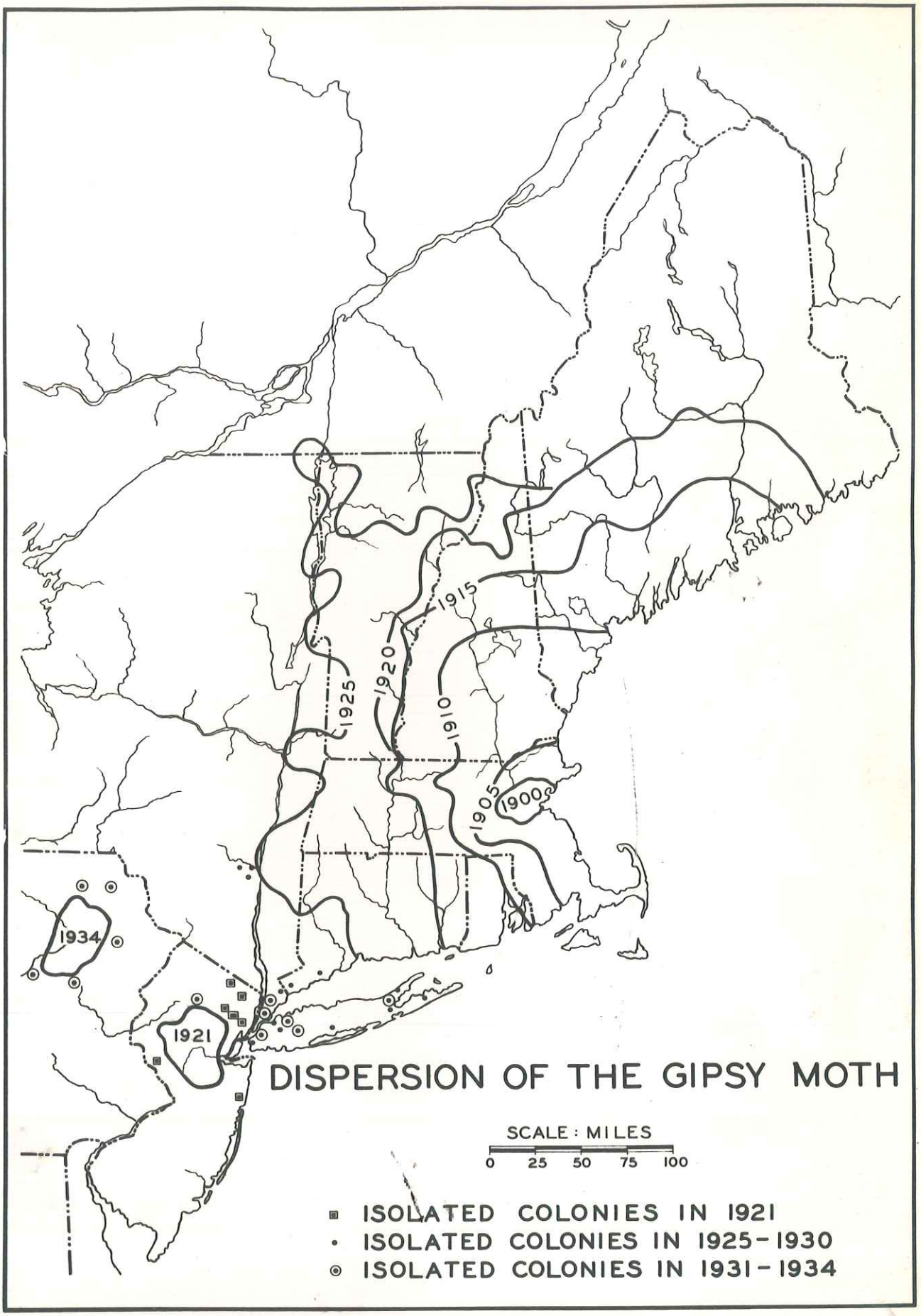
N.E.F.E.S. FILE No. A-49

D.F.B.-1936

Figure 1

Figure 3.


FOREST REGIONS
White Pine
Allegheny Hardwoods and Hemlock
Pine and Oak
Oak
Northern Forest
LAKE ONTARIO
LAKE ERIE
N.Y.
VT.
ME.
N.H.
MASS.
CONN.
R.I.
FOREST REGIONS
OF THE
NORTHEASTERN UNITED STATES
MILES
0 25 50 75 100



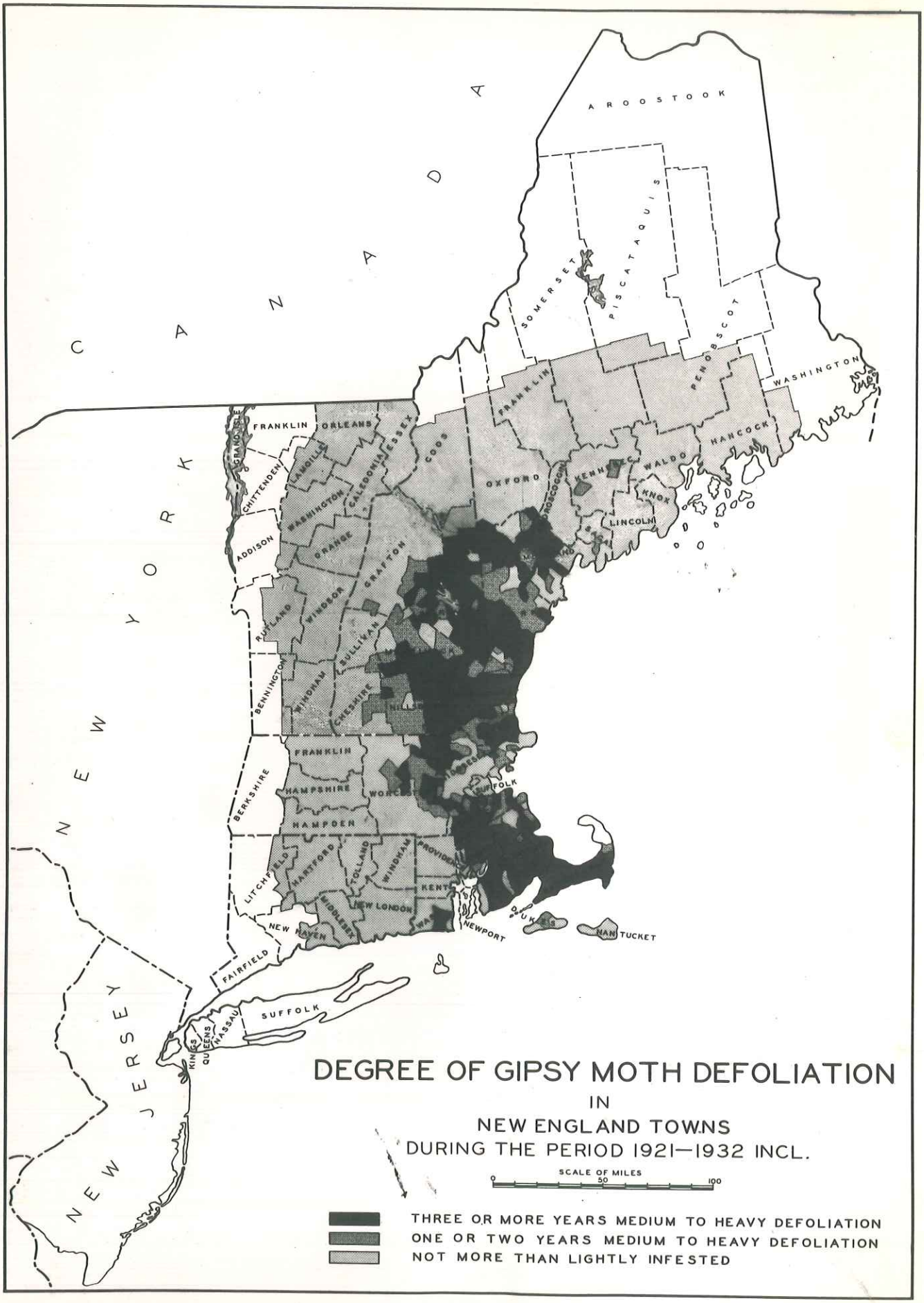
DISPERSION OF THE GIPSY MOTH

SCALE : MILES

0 25 50 75 100

- ▪ ISOLATED COLONIES IN 1921
- • ISOLATED COLONIES IN 1925-1930
- ⊙ ISOLATED COLONIES IN 1931-1934

N.E.F.E.S. File No. X-110.



DEGREE OF GIPSY MOTH DEFOLIATION

IN

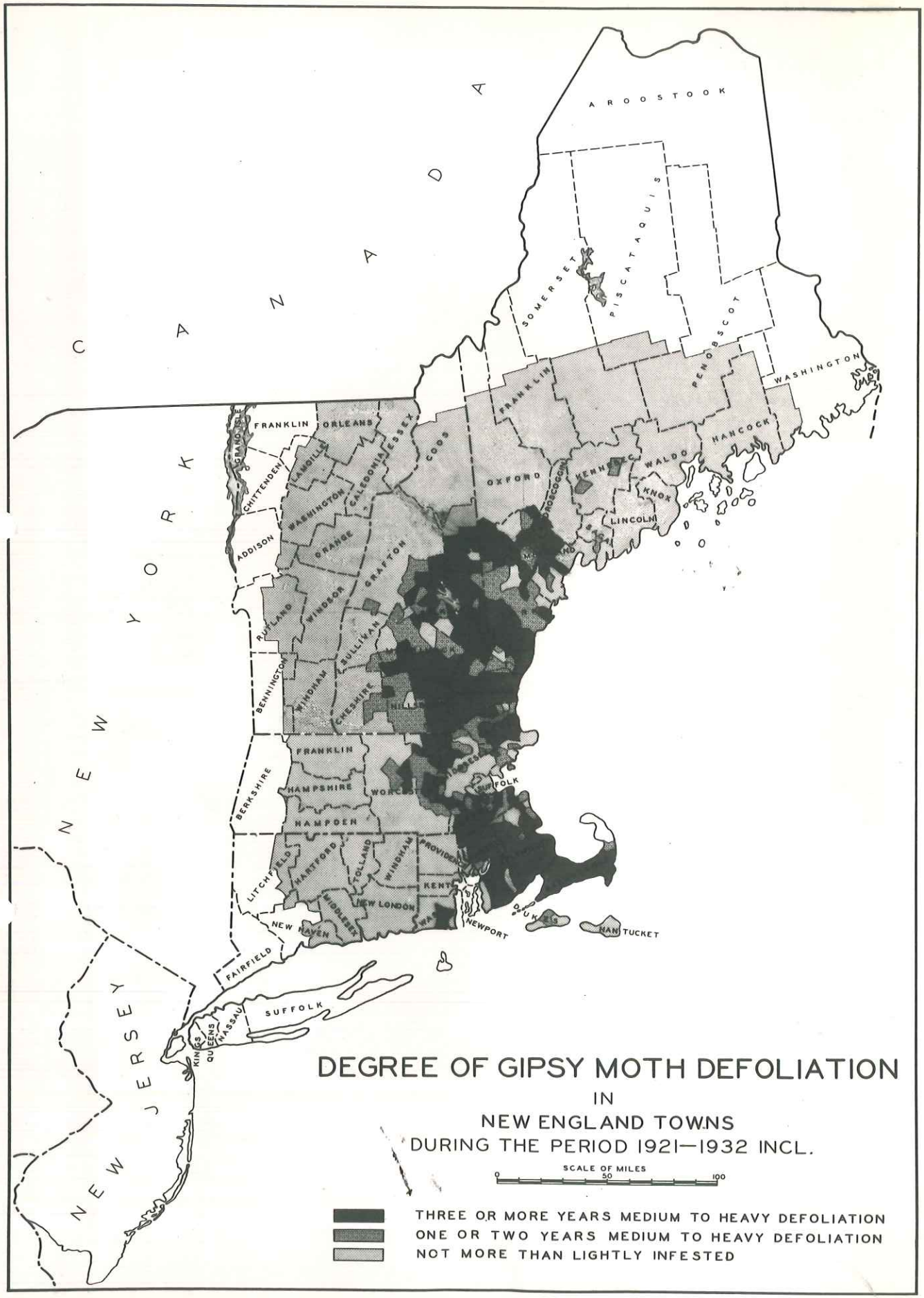
NEW ENGLAND TOWNS

DURING THE PERIOD 1921—1932 INCL.

SCALE OF MILES
0 50 100

THREE OR MORE YEARS MEDIUM TO HEAVY DEFOLIATION
ONE OR TWO YEARS MEDIUM TO HEAVY DEFOLIATION
NOT MORE THAN LIGHTLY INFESTED

N.E.F.E.S. FILE No. X-112



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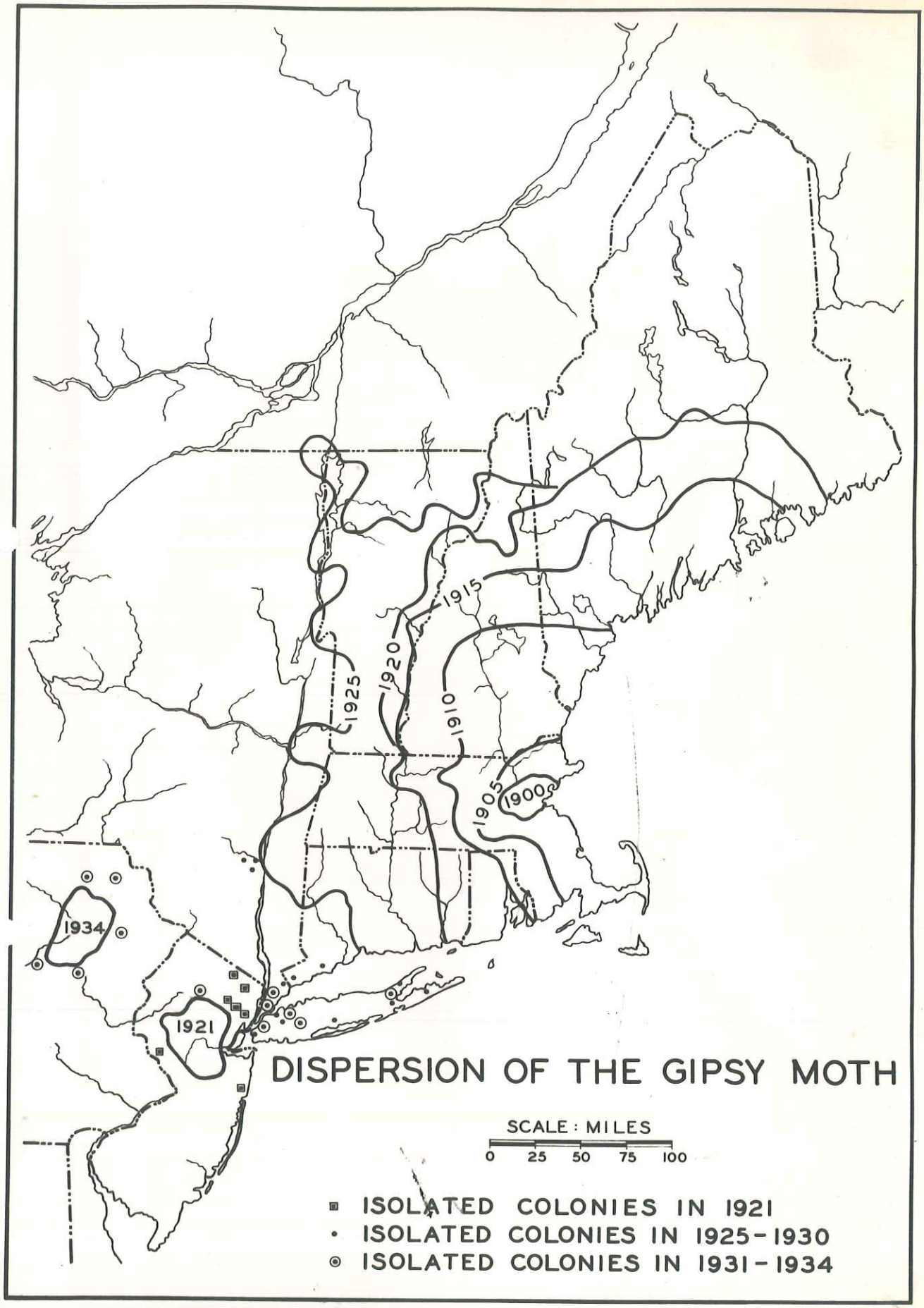


DISPERSION OF THE GIPSY MOTH

SCALE : MILES

0 25 50 75 100

- ■ ISOLATED COLONIES IN 1921
- • ISOLATED COLONIES IN 1925-1930
- ◉ ISOLATED COLONIES IN 1931-1934

N.E.F.E.S. File No. X-110.

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.

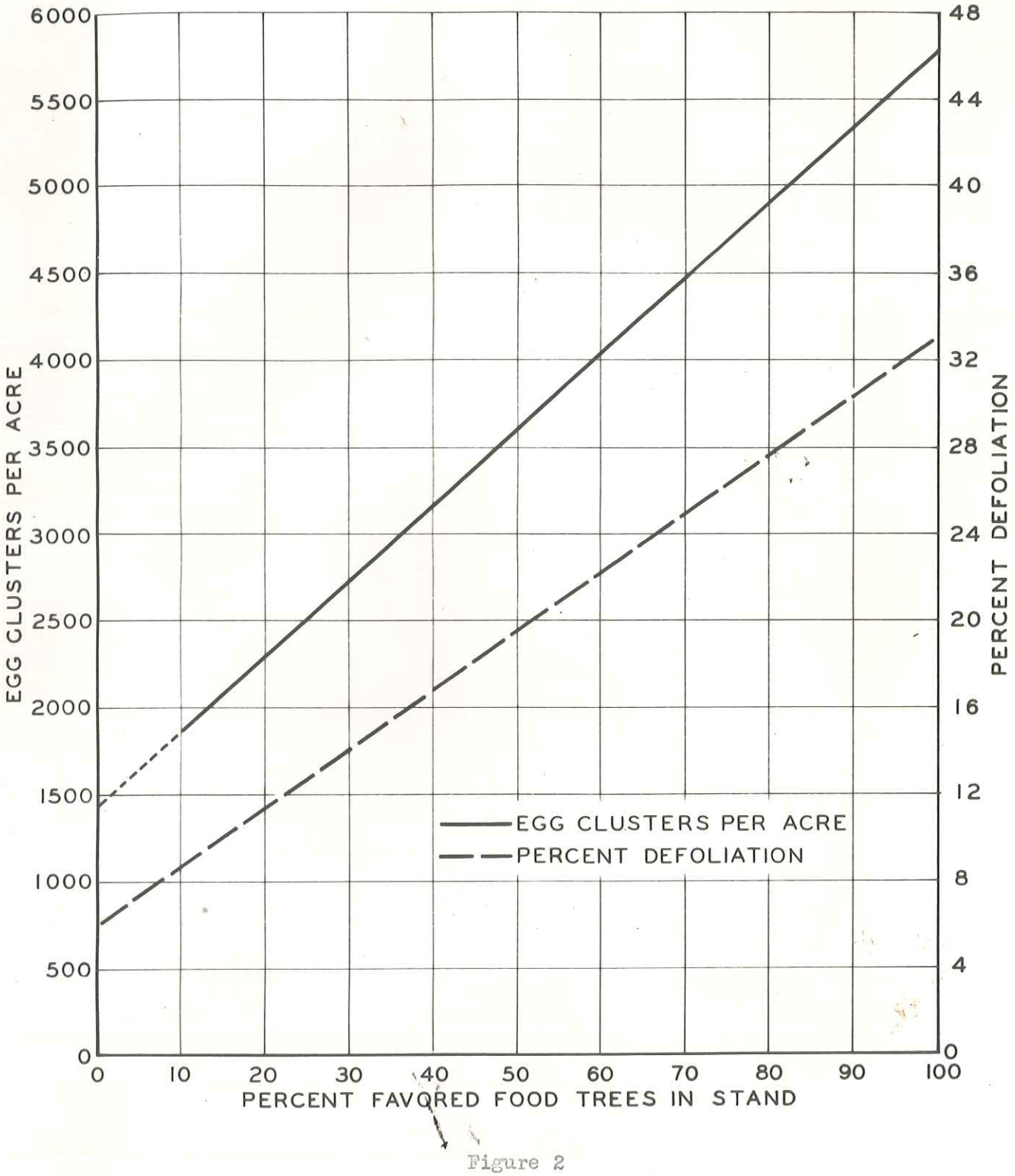


Figure 2

N.E.F.E.S. File No. X-109

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.

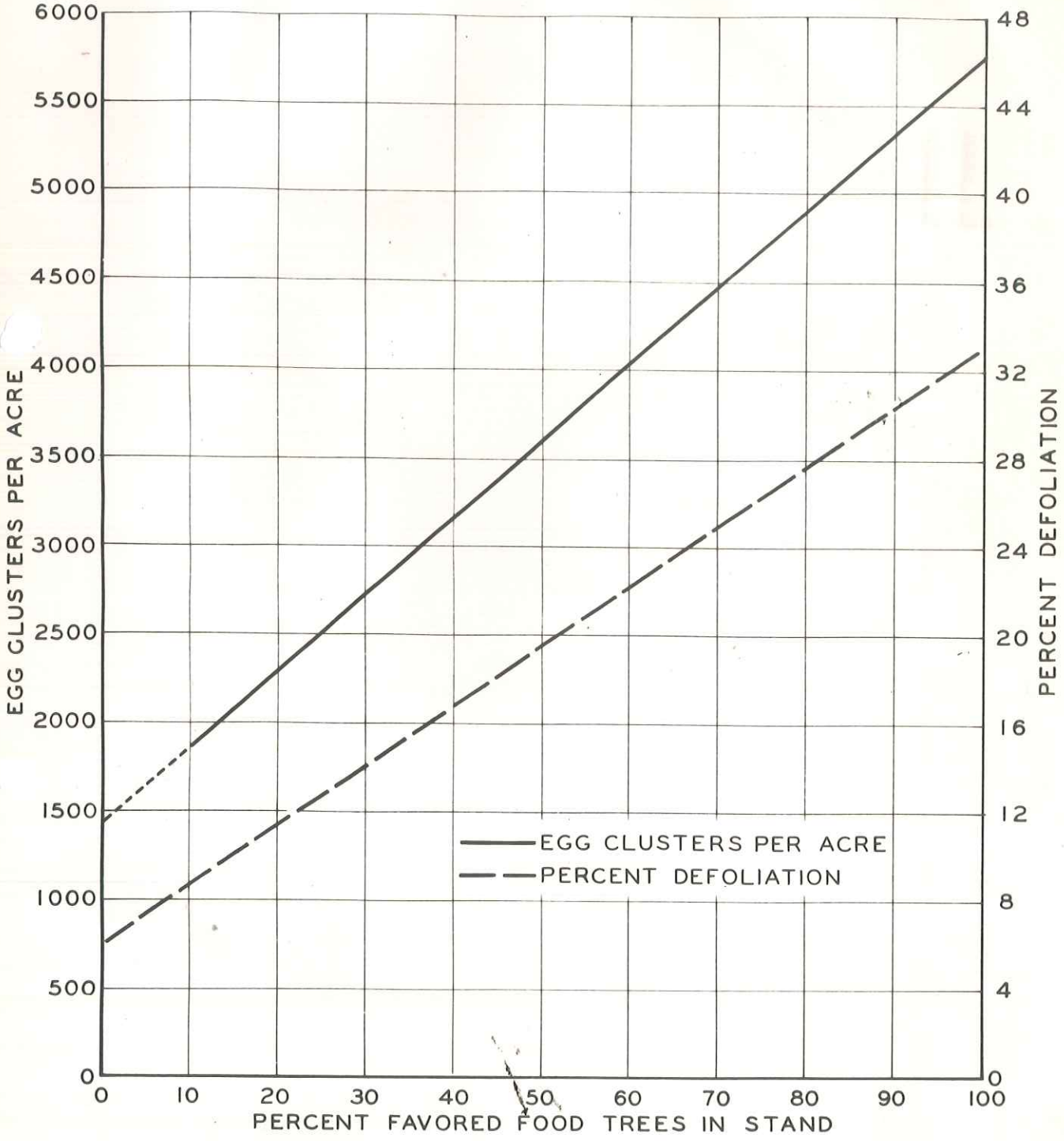


Figure 2.

N.E.F.E.S. File No. X-109

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.

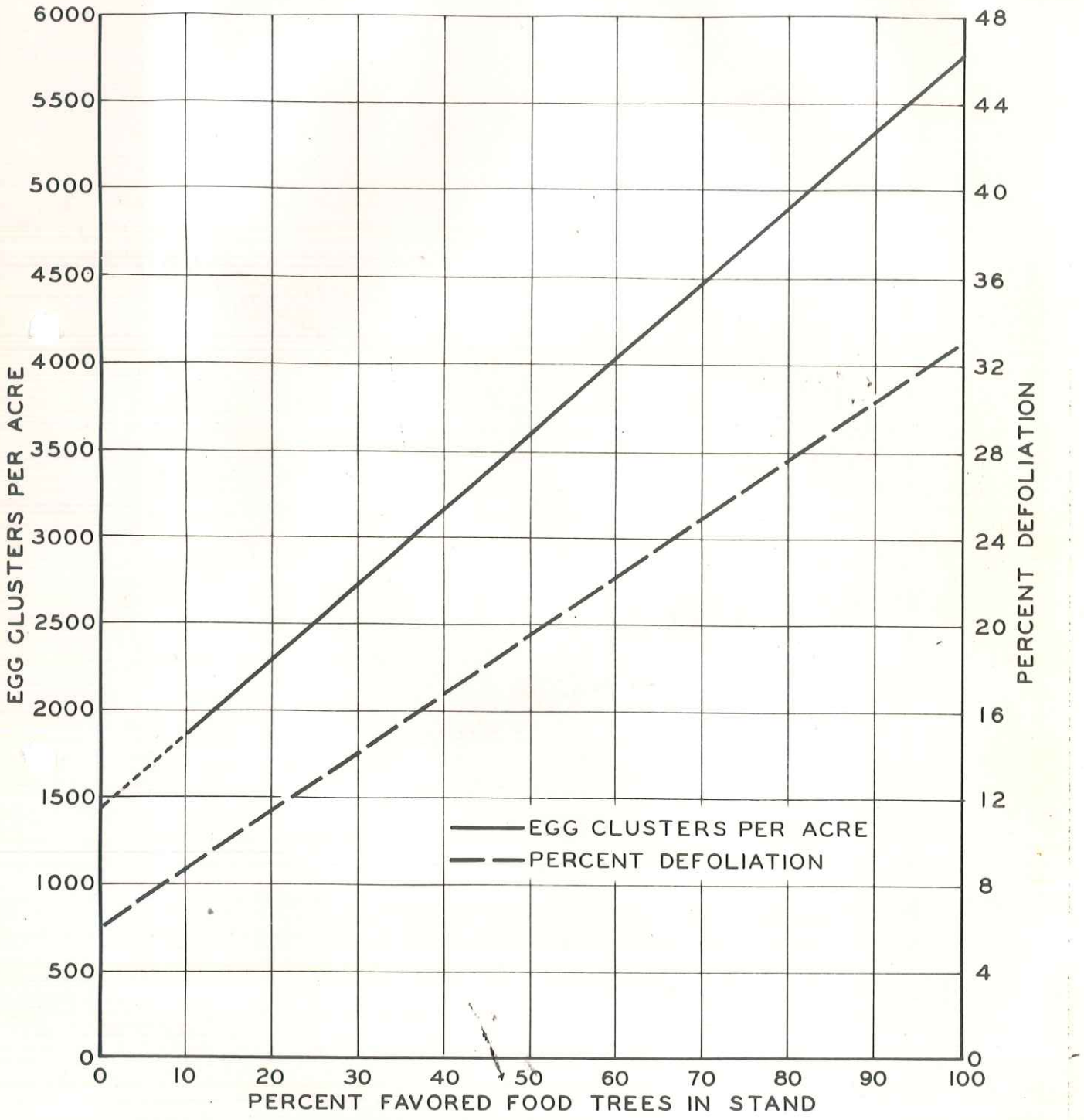


Fig. 3.

N.E.F.E.S. File No. X-109

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.

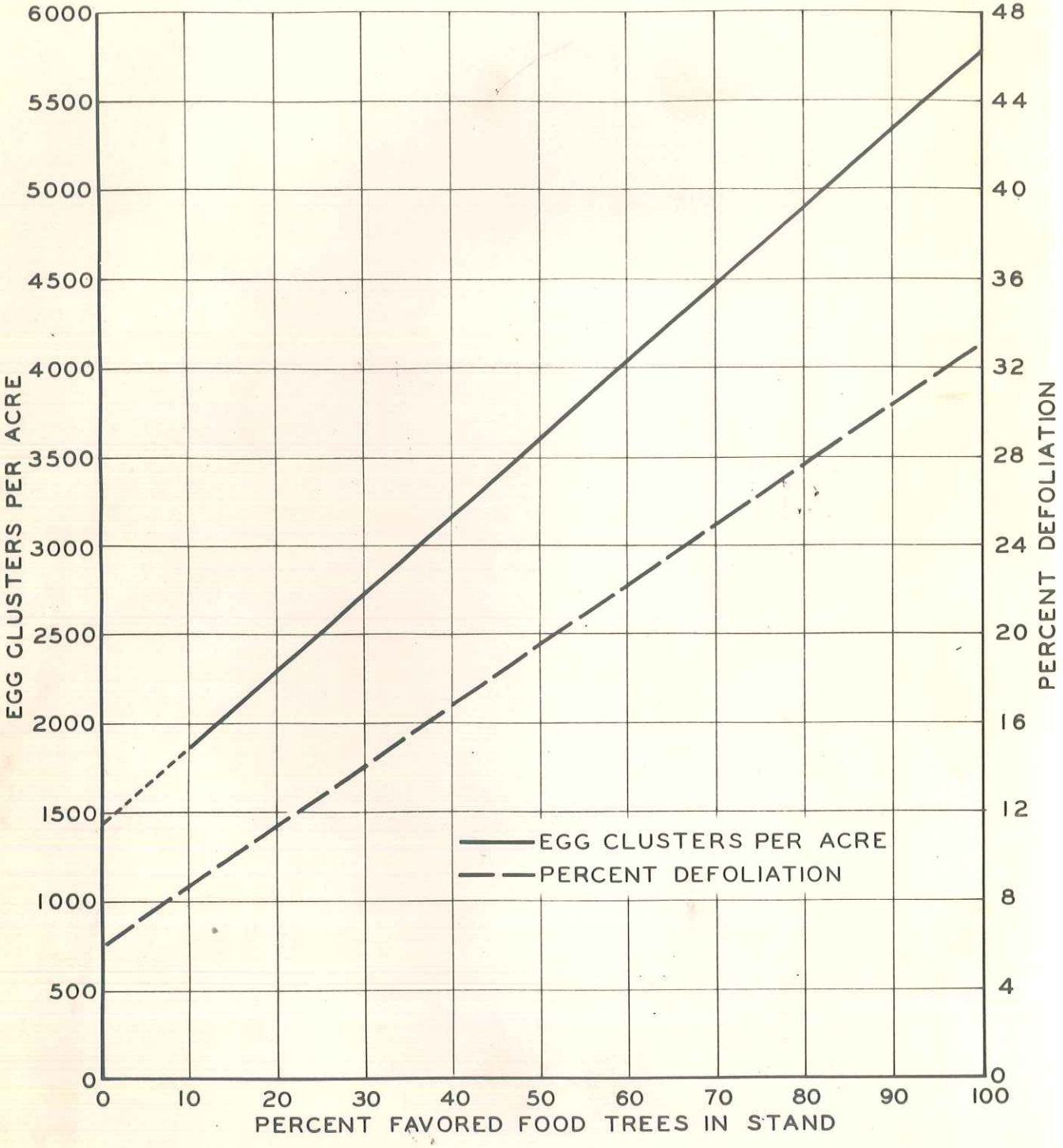
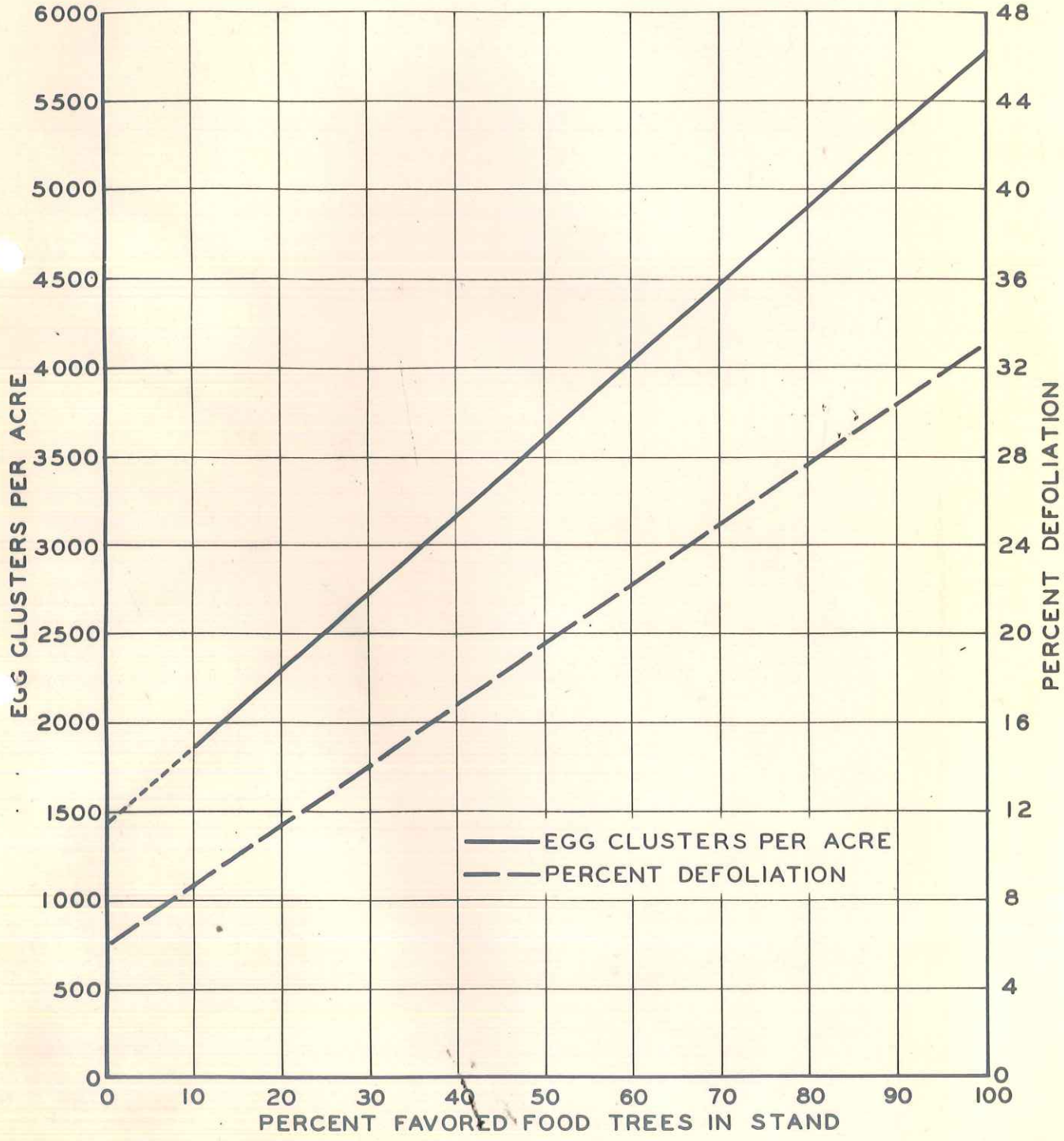


Figure 2.

4½" base 3"

N.E.F.E.S. File No. X-109

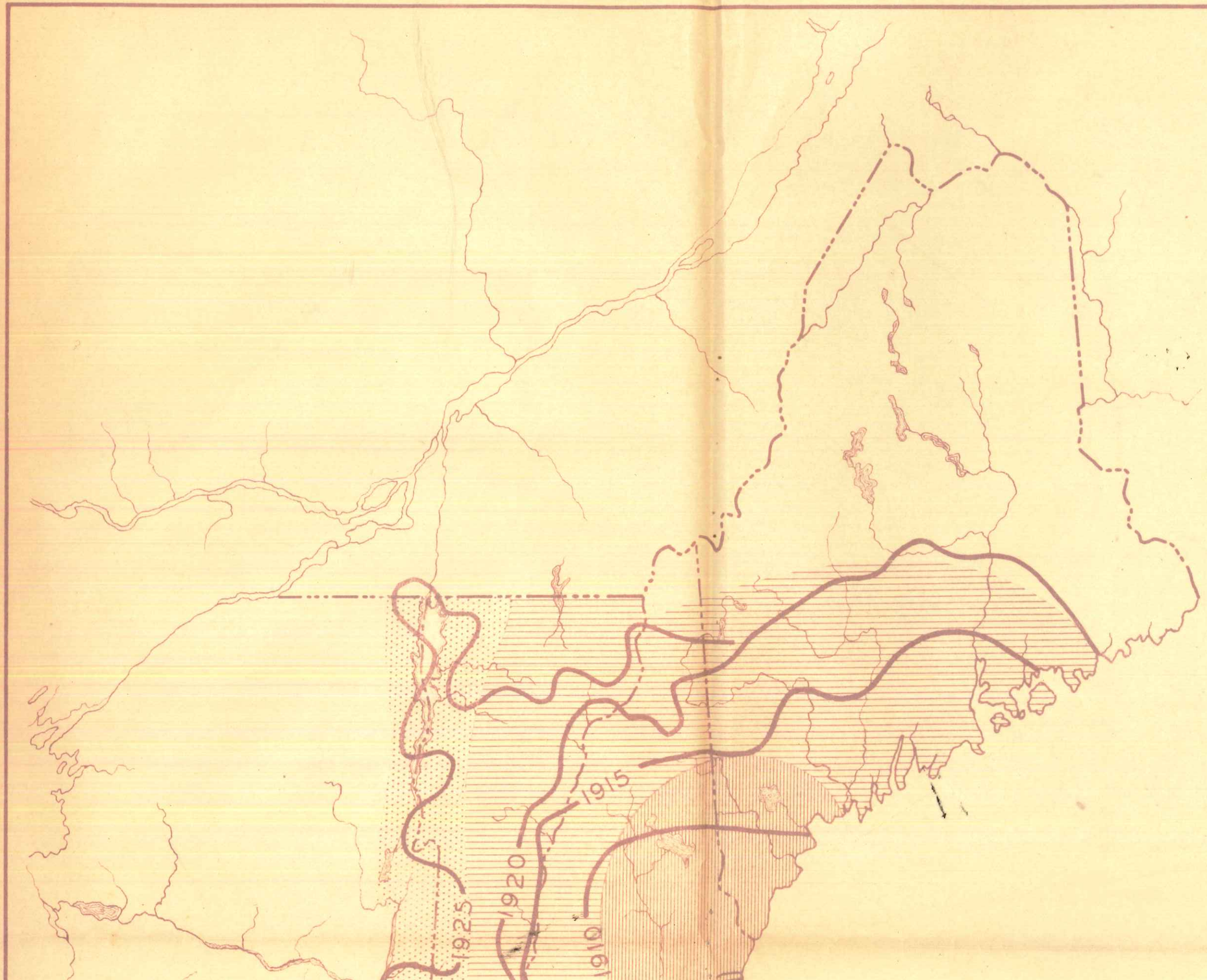
THE RELATION BETWEEN PROPORTION OF FAVORED FOOD PLANTS IN THE STAND AND INTENSITY OF GIPSY MOTH INFESTATION AND DEFOLIATION. RECORDS FROM 104 WOODLAND PLOTS FOR A 10 YEAR PERIOD. 1912–1921.

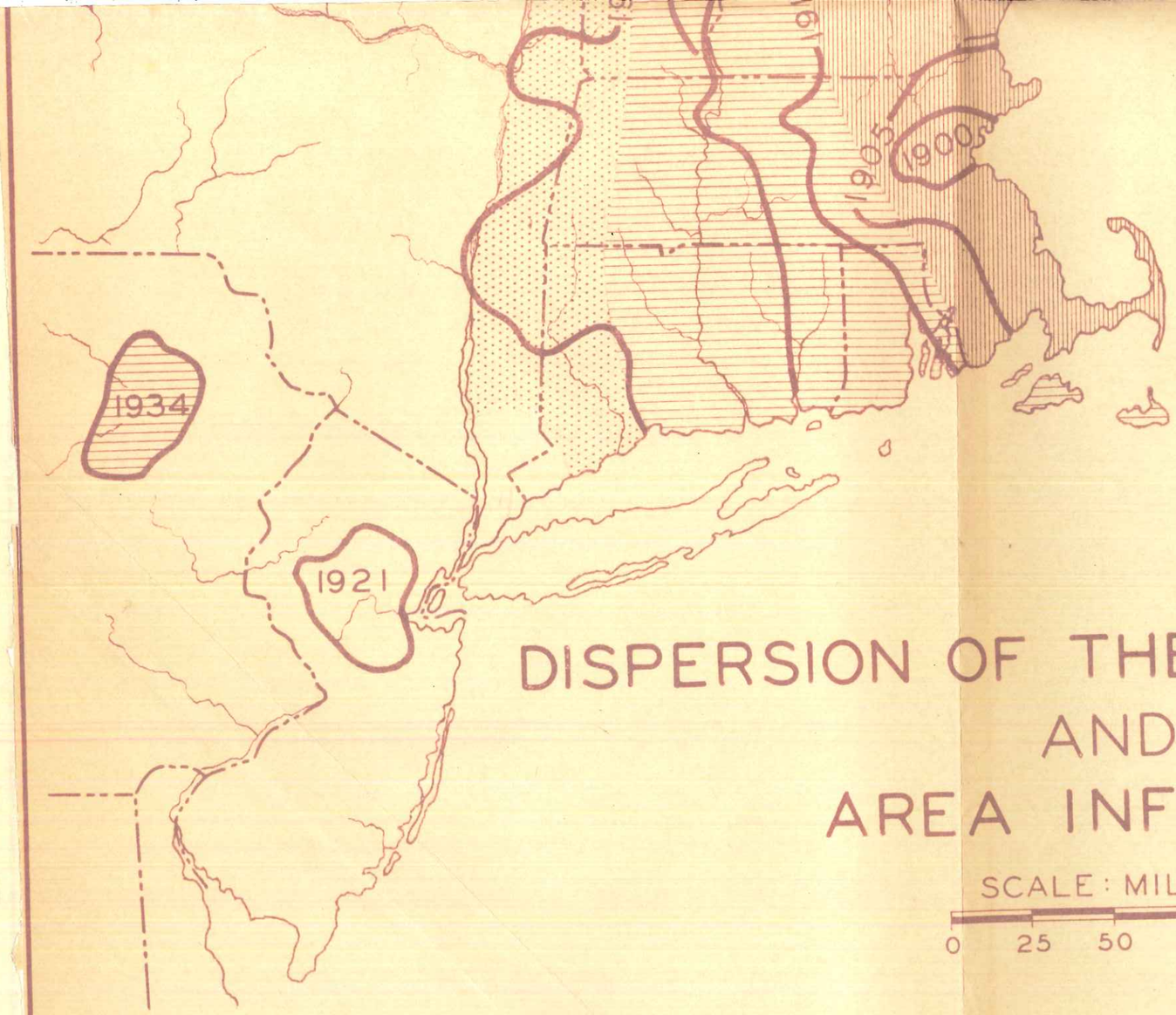


N.E.F.E.S. File No. X-109

Table Showing a Comparison between 4 Massachusetts Towns as to Distribution and Abundance of Favored Food Plants. These Towns are on Practically the Same Latitude.

Location of Sample Area	All favored Food Species		All Species of Oaks	
	Proportion of plots containing favored food trees	Proportion of plots containing a majority of favored food trees	Proportion of plots containing oak	Proportion of plots containing a majority of oaks
Beverly, Mass.	80.0%	33.0%	56.6%	16.6%
Concord, Mass.	94.0	54.0	79.0	37.0
Petersham, Mass.	85.0	19.0	56.5	2.1
Savoy, Mass.	51.0	4.6	0	0


1925
1920
1915
1910



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

D.F.B.-1936

N.E.F.E.S. FILE No. A-49

Figure 1.

PETERSHAM, MASS.

SCALE

1 INCH = 1/2 MILE

Hubbardston

Phillipston

PROSPECT HILL TRACT

Location of Harvard Forest Headquarters

HIGGINSON LOT

TOM SWAMP TRACT

SLAB CITY TRACT

Petersham P.O.

Reservoir

Reservoir

TOM SWAMP TRACT

Petersham P.

Reservoir

SLAB CITY TRACT

SCHWARZ LOT

HARVARD FOREST

Infestation Centers
A,B,C,D,E,F,

Waterways ---------

Road _____

Total miles = 75 1/4

#42

PETERSHAM, MASS.

A Study of the Gypsy Moth in the Town of Petersham, Mass., in 1935

BY

W. L. Baker and H. J. Mac Aloney, Bureau of Entomology and Plant Quarantine, and A. C. Cline, Harvard Forest.

For many years the gypsy moth, Porthetria dispar L., has been recognized as one of the most dangerous forest insect defoliators in the Northeast. In the 45 years which have elapsed since it first attracted notice in Medford, Mass., it has spread in all directions until at the present time a considerable portion of New England is infested. So serious did it become that in 1923 a "barrier zone", varying in width from 25 to 30 miles, was established in the western part of New England from the Canadian border to Long Island Sound. In this zone the Bureau of Entomology and Plant Quarantine has carried on an intensive eradication program in order to prevent the western spread of the insect. A rigid quarantine to prevent the accidental carrying of the insect beyond the barrier zone has also been in effect for many years. A few infestations have occurred outside of New England, the most serious of which were located in New Jersey in 1920 and in Pennsylvania in 1932. The New Jersey outbreak has been almost completely eradicated, but the Pennsylvania infestation is not yet under control.

In some years in New England the number of acres defoliated, in varying degrees of intensity, runs into the hundreds of thousands. The section most seriously affected is the pine-oak forest region of Cape Cod in Massachusetts. There are, however, large areas east of the barrier zone where the insect has been present for many years but has never reached outbreak proportions. Observations have been made over a sufficient period, and over a region sufficiently large, to indicate that the insect can find conditions favorable for increase to dangerous intensities only in certain regions and in certain types of forest growth. The fact has long been known that it will thrive on the foliage of certain species of trees and will die where confined to the foliage of others. Some twenty years ago

data on feeding habits were collected to form the basis for a table showing all the various tree species grouped in order of preference.

Furthermore, the preference for certain types of foliage is not constant for all of the larval instars (the periods of growth between molts). For example, the foliage of the oaks is desirable throughout the entire larval period; that of the maples is not desirable but will be fed on slightly, in the absence of more favorable food, by all instars; that of white pine is refused by the early instars but is very palatable to the larger larvae; while that of the ash is refused by all instars. In cases of heavy defoliation in mixed stands composed of both favored and unfavored species where there is sufficient favored food for the younger larvae to develop, the unfavored species may in some cases be completely defoliated. This has given rise to the belief that any and all species are favored. The fact is that unless some of the highly favored species are present in, or near, a stand of less favored species, no appreciable feeding on the latter will result. In New England those species highly favored by larvae of all ages are chiefly the oaks, poplar, gray birch, alder, and apple.

The purpose of the present investigation was somewhat two-fold in nature; (1) to study the reactions of the insect to its food supply in a region never before heavily defoliated, in order to determine if it had increased to outbreak form irrespective of food plants, or had only done so in concentrations of favored food; and (2) to determine to what extent any discriminating food habits of the insect, which might be discovered, would permit the practical application of silvicultural measures of control in a particular locality. Data have been obtained for a number of years bearing on this phase of the gypsy moth problem. In 1917 Clement and Munro (1) concluded that control could be effected by the removal of all the highly favored species from a stand. It was suspected then that the removal of only a certain percentage of the favored trees would prevent

injurious defoliation, but there was not, at that time, sufficient evidence to warrant definite recommendations. Much of the information which has been made available more recently is based upon a large number of 1/5 acre sample plots established by the Gypsy Moth Laboratory in 1911-12, distributed from southeastern Massachusetts to south central New Hampshire and southeastern Maine, and representative of a great variety of forest cover types. Each tree over 3" in diameter breast height was individually observed and recorded by number. At the start 264 plots were established, but owing to fire, cutting, etc. the number of useful plots was reduced to 104 ten years later. Figure No. 1, recently prepared, shows the relation between percentage of favored food trees in the plots and the intensity of infestation as measured both by egg masses and defoliation. It is based on 104 plots and the ten-year period from 1912-21, inclusive. This graph, it will be observed, represents average conditions and shows beyond reasonable doubt that the food supply is a controlling agent of the gypsy moth. The importance of this cannot be overemphasized. For one thing it means that an enormous amount of mixed woodland growth may be infested but not seriously injured, and that it should be unnecessary to remove all favored food trees in such mixed growth to bring about adequate control.

Since silvicultural practice as well as forest cover types and conditions for infestation vary from one locality to another, it is desirable, particularly from a forest management standpoint, to make such local and detailed intensive observations as will serve as a basis for specific cutting plans to alter or correct stand composition. With all these facts in mind it was considered worth while to make further observations under actual field conditions. The season of 1935 offered an exceptional opportunity, in central Massachusetts, for making such observations, since it represented the first epidemic outbreak of the insect in the region.

Petersham, Massachusetts, was selected as the town for study, first because

of its location with respect to the 1935 outbreak, and second, because of the presence, within its boundaries, of the Harvard Forest. The study was started independently by the Harvard Forest, and concluded as a cooperative project of that institution and the Bureau of Entomology and Plant Quarantine.

Petersham turned out to be an ideal town for studying the outbreaks, because of the nature of its forested land and its hilly terrain. It is characteristic of a considerable portion of north-central Massachusetts and the nearby towns of southern New Hampshire. The rolling nature of the countryside made it possible to see every completely defoliated (browned) area in the town from one vantage point or another. Land history was such that a great variety of contrasting cover types were present, temporary as well as permanent, and numerous small stands of favored food trees were intermingled with stands of strikingly different composition. A forest type map of the town (about 22,000 acres in extent) would show approximately 5000 separate stands.

The defoliated areas were located and plotted on a topographic map (Figure 2). There were 82 such areas and 81 of these were actually visited and studied by the authors. During the course of travel to these areas, constant watch was kept for gypsy moth larvae, and invariably some were found wherever favored food trees were growing. This indicated that the insect was generally present throughout the entire town, although complete defoliation occurred in only the 82 areas.

In the defoliated areas the stand composition and the average per cent defoliation suffered by each species were determined by ocular estimation. The defoliation was arbitrarily considered as None, Trace, 25%, 50%, 75% and 100%. It was impossible, and unnecessary from a practical standpoint, to measure these factors more accurately, because the time available for the study was limited to the two week period when defoliation was at its maximum

and refoliation had not begun. The data obtained from the defoliated areas are summarized in Table I, and shows a definite correlation between the degree of defoliation and the proportion of highly favored food trees in the stand.

The results in this figure show very conclusively that concentrations of species favored as food by all larval instars accounted for the conspicuous defoliated areas in the town of Petersham. It will be noticed that complete defoliation was not observed in any instance where favored food trees constituted less than 50% of the stand. In 70% of the defoliated areas oak, gray birch, and poplar comprised more than 75% of the stand, thus showing the outstanding importance of these three species in creating a suitable environment for the gypsy moth.

Invariably it was observed that the heavy defoliation was strictly limited to stands or portions of stands composed wholly or largely of favored food trees, and that the severe defoliation came to an abrupt stop with changes in composition of immediately adjoining stands. In addition to the information from the 81 defoliated areas, data were also obtained in some cases from the lightly defoliated margins of adjoining stands. A comparison of composition and defoliation under the two conditions is shown for 13 cases in Figure 3. Marked differences in composition are at once evident. Favored food trees comprised 89.5% of the average defoliated stand, but only 19.3% of the average margin of the adjoining stand. What little defoliation occurred in the latter very evidently was largely due to migrants from the defoliated stand of favored trees, since feeding in the unfavored stand was limited to a narrow margin. In several cases where narrow strips of unfavored species separated heavily defoliated stands of favored species, the former showed only a trace of feeding--further proof of the discriminating feeding habits of the moth.

Relation between Proportion of Favored Food trees in the stand and the Gypsy Moth. Data from Woodland plots visited twice yearly for 10 successive years.

Percent Favored Food* Trees in stand	Egg Clusters Per Acre	Mean Per Cent Defoliation of all Trees**
0	1522	8.0
0-9	1787	6.8
10-19	1955	9.7
20-29	2957	13.4
30-39	3639	16.3
40-49	3906	18.0
50-59	3361	15.5
60-69	3659	27.9
70-79	4132	27.2
80-89	7914	32.4
90-99	3954	32.2
100	9901	32.5

* According to authority 1915.

** Defoliation measured each year during 10 year period.

I

Correlation of Occurrence of Certain Tree Species

and Heavily Defoliated Areas in the Town of Petersham (1935)

Species and Combinations of Species	Cases Where Species Comprised 50-75% of Stand		Cases Where Species Comprised 75-100% of Stand		Cases Where Species Comprised 50-100% of Stand	
	Number	Per Cent	Number	Per Cent	Number	Per Cent
White Oak	0	0.0	0	0.0	0	0.0
Red Oak	2	2.5	0	0.0	2	2.5
Aspen (2 species)	8	10.0	4	5.0	12	15.0
Gray Birch	13	16.2	21	26.2	34	42.4
Gray Birch and Aspens	18	22.5	39	48.7	57	71.2
Gray Birch, Oaks, and Aspens	20	25.0	56	70.0	76	95.0
Gray Birch, Oaks, Aspens, and Alder					81	100.0

Fig 3.

Comparison of Defoliated Stands with the Contiguous but Distinctly Less Defoliated Marginal Stands*

Plot No.	Average Composition: Favored Food In Defol. Area Per Cent	Average Composition: Favored Food In Marginal Stand Per Cent	Average Defoliation: Favored Food in Defol. Area P	Favored Food in Marginal Stand B R C	Unfavored Food in Defol. Area E N	Unfavored Food in Marginal Stand T	Defoliation of All Trees in Defol. Area Per	Defoliation of All Trees in Marginal Stand Per Cent
11	86	12	87	33	37	5	80	9
16	86	21	91	91	58	11	86	28
24	87	15	100	24	54	6	94	8
38	92	19	100	10	47	0	96	2
39	95	1	100	0	100	0	100	0
40	97	32	85	44	75	6	84	18
(NE)41B	91	10	99	36	50	17	95	19
(W) 41B	91	16	99	37	50	15	95	17
42	90	51	96	26	34	3	90	14
51	91	35	100	14	72	9	98	11
71	83	5	100	100	54	11	92	15
72	87	15	87	8	55	5	83	6
Mean	89.5	19.3	95.3	35.3	57.2	7.3	91.1	12.2

* Note particularly the difference in composition between the heavily defoliated stand and the margin of the adjoining stand.

The findings of this study are such as to warrant the following specific recommendations for the control of the gypsy moth through a program of silvicultural treatment, where conditions are similar to those in Petersham.

Coniferous Plantations

As previously stated, the older larvae find coniferous foliage a desirable food. Since conifers, with the exception of larch, lack the ability to refoliate following complete defoliation and since plantations represent a comparitively large investment in new growing stock, the protection of plantations of conifers is placed first on the list of priorities in treatment.

In Petersham both gray birch and poplar very commonly seed into old fields and pastures, either before or after plantations are established. On cutover lands these species oftentimes are supplemented by sprouts of red and white oak. The newly hatched caterpillars are able to develop on any and all of these hardwood species. Following complete defoliation the larvae, if they have reached the third instar, can easily migrate to the conifers and defoliate them. Thorough clearing of the planting site prior to planting and the timely application of weeding thereafter will serve the needs of both silviculture and protection. Severe damage to coniferous plantations is usually a case of neglect to weed, for nothing is to be gained by allowing a good plantation to be whipped and suppressed by overtopping hardwoods of little or no value, and not intended as part of the crop. It is true, of course, that a hardwood "filler" has proved advantageous in improving the quality of conifers, but in a properly managed stand such a filler is kept below the conifers and not above. Even so, where it is made up largely of gray birch, as is sometimes the case, it may be advisable to remove it. Loss of quality in the butt log is of less concern than defoliation of the tree.

Underplantings

Underplanting has been used very little locally; but where it has, conditions usually are favorable for moth attack. This is because gray birch and poplar are among the species commonly thought suitable for an overstory. Here the treatment is plainly one of cutting the birch or poplar overstory, even though it may be furnishing protection to the conifers against white pine weevil attack, and may be too small in size to make cordwood. Conifers growing directly beneath a canopy of favored food trees are very apt to be seriously defoliated. At the same time, it is recognized that sudden and complete release from partial suppression may result in damage from snow or ice. In some cases releasing may require two steps; the first one reducing favored food tree foliage as much as possible without jeppardizing reasonable security against bending and breaking with snow or ice loads. The final removal cutting would be made a few years later, when the conifers had sufficiently strengthened their stems to withstand the elements.

Coniferous Understories of Natural Origin

From the standpoint of control measures, conditions here are much the same as those just discussed under "Underplantings". Very frequently pine and gray birch seed in simultaneously in old fields and pastures; but although both elements are of the same age, the birch soon overtops the more slowly growing pine, arrests its growth by whipping off the buds, and in time often completely suppresses it. The obvious treatment is the cutting of the birch before suppression of the pine has reached a critical stage, and before a moth colony becomes established.

It is to be noted that, almost without exception, both coniferous plantations and natural coniferous reproduction, whether on old fields or cutover land, contain more or less weed hardwoods of the favored food species, and that the prompt elimination of such is demanded as sound silvicultural practice as well as a protective measure.

Isolation Strips

Several cases were observed where the margins of coniferous plantations growing next to stands composed wholly or largely of gray birch, poplar, alder, or oak were defoliated. It is evident that the removal of favored food trees from within plantations or young coniferous stands of natural origin must be supplemented by cutting a protective strip wherever such hardwoods occupy adjoining areas. On the basis of several observations, it would seem that, under local conditions, a cleared strip about 100 feet wide should be sufficient to prevent any serious defoliation along the margin of the coniferous stand.

Mixed Stands of Pine and Better Hardwood

There were a few cases noted where some defoliation of pine occurred because of its association with red and white oak. Such mixtures are found on the lighter soils, or on exposed southern slopes and ridge tops. It is not a common condition in Petersham. In middle-aged or maturing stands of this composition, the pines generally were not defoliated to such an extent that they will die, except perhaps where they formed a minor element in the mixture. However, defoliation might in some cases be severe enough to warrant protective treatment, and this would take the form of a cutting to reduce the quantity of oak foliage. It is believed that a reduction to about one-half that of the pine will assure safety of the latter from heavy defoliation, but further observations are needed on this point. Where

conditions of ownership and merchantability warrant the complete elimination of the oak, any sizeable opening made by cutting might be planted to conifers, thus forming a groupwise coniferous mixture of two or more age classes.

On the Harvard Forest, young, groupwise mixtures of conifers and better hardwoods, including in some instances a substantial proportion of red oak, may require protective treatment. Since, on the heavy soils, where such mixtures are being developed, there is a large variety of hardwoods available for the crop, the treatment will consist of a reduction in the proportion of oak and a corresponding increase in that of such species as white ash, hard maple, and paper birch. This alteration in composition can be done in the course of weedings and improvement cuttings regularly carried out in such stands. It is probable that reduction of oak foliage to somewhat less than half the total for all hardwoods in a given group will afford adequate security to the neighboring coniferous group. Because of the aggressive habit of red oak and its strong tendency to crowd out other valuable hardwood species, a reduction in the proportion of this species, especially through cutting the coarser individuals, is considered desirable from the standpoints of high quality crop production and a well-balanced mixture, regardless of its protective value.

Stands of Mixed Better Hardwoods

With a few exceptions such stands in the town of Petersham fall within the so-called Transition Hardwoods type, which is composed of a considerable variety of commercial species representative of both the Northern Forest and the Central Hardwood Forest. It is to be noted, however, that, since the death of chestnut, red oak is the most aggressive species in the mixture; and in many stands of middle age or older, it predominates to the extent of occupying a larger proportion of the crown canopy than all associated species combined. For the most part, the latter are unfavored food species. In order to avoid recurrent defoliation of the oak, particularly where it occurs in groups, with at least a resultant slowing down in growth,

some alteration in stand composition is indicated. Under local conditions, it is believed that a reduction in the volume of oak and other favored foliage to an upper limit of one-half of the total for the main canopy will afford satisfactory protection. Depending upon age, density, and relative proportions of favored and unfavored species, such a reduction will require one or more cuttings covering a period of years. These may well be combined with the ordinary types of improvement cuttings and thinnings applicable to such stands.

Stands of Favored Weed Species

Stands of gray birch or poplar, or mixtures of the two, occur commonly throughout the town. As shown in the tables, these provided the chief sources of infestation. Though neither species is sufficiently valuable to warrant much concern over its protection, there are places where the owner may wish to avoid further trouble. Plainly the only possible method of silvicultural control is clear-cutting followed by planting. On the best soils hardwoods of unfavored species or mixtures of such hardwoods and conifers may be used; on the lighter soils, conifers alone. Such complete conversions from weed hardwoods to valuable sawtimber species is, of course, a part of the usual plan of management on the organized forests.

The conditions cited above are the ones commonly found in Petersham. They are by no means representative of the entire region infested by the gypsy moth. It is believed, however, that measures of indirect control through silvicultural treatment must be worked out locally, and that the observations of the past season in this particular town and the conclusions drawn therefrom contribute towards this end.

SILVICULTURAL CONTROL OF THE GYPSY MOTH

By

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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. To prevent the 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 1924. The zone lies in western New England and in New York state, east of the Hudson River. Here scouting is carried on continuously and all infestations discovered are promptly eradicated. Outside of New England a few isolated infestations, chiefly in Pennsylvania, are being vigorously attacked with the expectation that they all may be eliminated.

Since the initial infestation in the vicinity of Boston, the general direction of most rapid spread has been toward the northeast (See Figure 1), no doubt a result of prevailing winds in this direction during the hatching season when young larvae are known to be carried by wind. During the early years of the record, however, it will be observed that spread was into southeastern Massachusetts, which has proved to be the most favorable environment in New England for the gypsy moth. Western spread in outbreak form had apparently ceased by 1920. But in 1934-1935 a new outbreak occurred in Massachusetts immediately west of the region formerly infested and east of the Connecticut River.

Infestation has been by no means uniform. The degree of defoliation by towns for the periods 1909-1920 and 1921-1932 is shown in Figures 2 and 3. In addition to southeastern Massachusetts, certain portions of southeastern New Hampshire, southwestern Maine and northeastern Massachusetts have been especially susceptible to attack. But it should be pointed out that even in towns rated as most heavily infested, many individual stands have entirely escaped severe defoliation.

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 through 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). But aside from actual loss of trees, protection of aesthetic values is of major importance in residential areas and in the outlying areas of woodland where recreational use is extensive. Greatly increased motor traffic on the highways and recreational use of the forests throughout the infested area demand freedom from the unsightliness of defoliation and the obnoxiousness of masses of caterpillars crawling over the ground and trees.

FEEDING HABITS

In its feeding habits the gypsy moth exhibits a marked preference for the foliage of certain species of trees. Broadly speaking, the common forest trees of New England may be classified according to favorableness, as follows:[1]

[1] Mosher, F. H. Food Plants of the Gypsy Moth in America. U.S. Dept. Agr. Bull. 250, 39 pp., 6 pl., 1915 (revised).

(1) Species highly favored by larvae in all stages

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

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

paper birch	larch

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

maple	yellow birch
elm	black birch
hickory	black gum
hornbeam	black cherry
sassafras	

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

pine	hemlock
beech	spruce

(5) Species not favored in any larval stage

ash	American holly
butternut	sycamore
dogwood	tulip poplar
balsam	black walnut
locust	southern white cedar
red cedar	

Stands composed entirely of species in class 1 may be entirely 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 pro-

portion 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 severely defoliated, although the likelihood is greater than in mixtures of 3, 4, and 5.

It is evident that the gypsy moth is largely dependent upon the distribution and abundance of certain species of trees. This may be made more specific by citing the results of an extensive study conducted by the Bureau of Entomology and Plant Quarantine over a 10-year period (1912-1921) in a series of 104 woodland plots in the eastern portion of the infested area. These plots were visited twice yearly, once in the summer to record the degree of defoliation and again in late autumn to record the number of egg clusters present. In Figure 4 these data are shown correlated with the proportion of favored to unfavored food trees. It will be seen that the average number of egg clusters per acre and the average degree of defoliation are directly proportional to the abundance of favored food trees.

This relation is further corroborated by a study of 81 of the 82 completely defoliated stands in the town of Petersham in 1935. In every case highly favored food species comprised over 50 per cent 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.

CONTROL

In general, two types of control of the gypsy moth are in common operation at the present time: namely, biological control and artificial control.

Biological control is concerned with the introduction and dissemination of parasitic and predaceous enemies of the gypsy moth from its native habitat in the old world. This work 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 outbreaks and lengthen the period between them. However, since epidemic outbreaks recur from time to time in spite of the presence of parasites, 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. Under certain conditions trees may be treated with bands of either a sticky substance, known as tanglefoot, or folded bands of burlap to prevent migrant larvae from ascending the trees. When thoroughly applied any of these methods is effective in protecting trees from injurious defoliation. However, the nature and cost of the work involved generally limits their application within the 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 the 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.

But the discrimination in feeding habits described above offers a key to a gradual but more permanent measure of control applicable over a considerable part of the infested territory; for, by silvicultural measures, the prevalence of favored food species can be reduced and less favored food species encouraged, thus creating conditions under which the likelihood of infestations increasing to epidemic proportions is minimized. The cost of such silvicultural measures will generally be commensurate with the values at stake, and indeed may often be more than repaid by the improved quality and yield of the final crop.

The desirability of placing increased emphasis on silvicultural control has been brought out by the severity of recent outbreaks in central Massachusetts, which not only have aroused the local people, but which indicate the inadequacy of the creosoting program alone in holding in check a potential threat against the Barrier Zone.

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 5, is therefore essential to consideration of possible control measures.

Northern Hardwood Region

The forest of northern New England and northern New York is predominantly composed of beech, hard 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. 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 cutover lands where stands of favored food species such as poplar and paper birch predominate, no serious outbreaks have occurred. Without doubt, climatic factors operate in the north to hold the gypsy moth in check. Effort at silvicultural control might well be concentrated in 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

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 Central Hardwood forest is composed very largely of species highly favored as food by

the gypsy moth, and this complicates the problem of obtaining effective silvicultural control. 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

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 than farther inland, and this region has been subjected to more frequent and severe outbreaks of the gypsy moth than 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.

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 agressive of the better hardwood species in this zone. Although a very desirable commercial timber species, it is, unfortunately, highly favored by the gypsy moth.

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.

BASIS FOR SILVICULTURAL CONTROL

Successional Trends 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 it is at present. With few exceptions the original forest types contained smaller percentages of favored food species than the secondary types which have followed as a result of cutting, burning, and clearing.

The 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 cleared 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 cutover 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 past farming and lumbering practices.

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 the influx of inferior species, cutting 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 the 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 clearcutting practices so prevalent in the past may be expected to reduce the abundance of light-demanding weed species most favored by the gypsy moth.

Thus the need for aggressive action to protect the forests from the gypsy moth should stimulate proper silvicultural treatment, now long neglected; 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.

THE APPLICATION OF SILVICULTURAL MEASURES OF CONTROL

Principles

Silvicultural measures for the 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

* Cline, A.C. Forest Weeding. 20 pp. illus. Mass. Forestry Association. 1929.

------ Improvement Cutting and Thinning. 16 pp. illus. Mass. Forest and Park Association. 1935.

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

In order to obtain reasonable security against damage from defoliation, the volume of favored food tree foliage should not constitute more than 50 per cent of the total for a given stand. 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 wood or timber values involved.

This order would not apply to 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~~ are 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) cutover 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, can be assured by the removal of intermingling or surrounding trees of species highly favored by the gypsy moth, because caterpillars cannot survive on the foliage of any of the conifers, except larch, 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 highly favored species 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 and oak in the White Pine and Central Hardwood Region, 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 hard-

wood growth is relatively slow, and under light-foliaged species such as poplar and gray birch.

Security from the gypsy moth demands the removal of the hardwood 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 the 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 growing with conifers must be supplemented by cutting a protective strip wherever stands of such hardwoods adjoin stands of conifers. 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 avoided by girdling instead 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 White Pine Region protection against the gypsy moth will be concerned for the most part with mixtures of pine with gray birch, poplar or oak; in the Central Hardwood Region with mixtures of pine or hemlock with oak; and in the Northern Hardwood Region with mixtures of spruce, balsam or pine with poplar. The extensive areas of spruce and balsam in mixture with yellow 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 a 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 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. Resulting openings may be restocked with resistant species, either through natural reproduction or by planting.

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. It should be understood that reduction to the extent recommended, namely, one-half, 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 mixed conifers and hardwoods in the sapling stages offer excellent opportunity for treatments to reduce the danger from the 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 being developed, 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 coarsest oaks in favor of such species as white ash, hard 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 red 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, hard maple, yellow birch 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. Red, white, black, scarlet, and chestnut oaks are all abundant. Such unfavored species as hard maple, beech, white ash, black cherry, and yellow birch are less common than in the transition zone. 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, black birch, etc., 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 neighboring oak groups. The 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 planted groups is not more than 20 years. It is suggested, because it does not involve the 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 the gypsy moth by clear-cutting and planting. Choice of coniferous or resistant hardwood species for planting will depend largely on the quality of the soil. Two or three weedings of the planted stands will be necessary to insure satisfactory development. In hardwood mixtures, favored for the heavier soils, no attempt should be made to eliminate the oak entirely, but rather the objective should be to develop a composition in which oak does not exceed one-half the total foliage volume, and in conifer-hardwood mixtures a composition in which the volume of oak foliage is not more than half as much as that of the coniferous foliage.

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 bear 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. Serious defoliation is not likely to develop where the volume of favored food tree foliage constitutes less than half of the total.

Increasing the proportion of woodland in which conditions are unfavorable to 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 crop improvement.

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

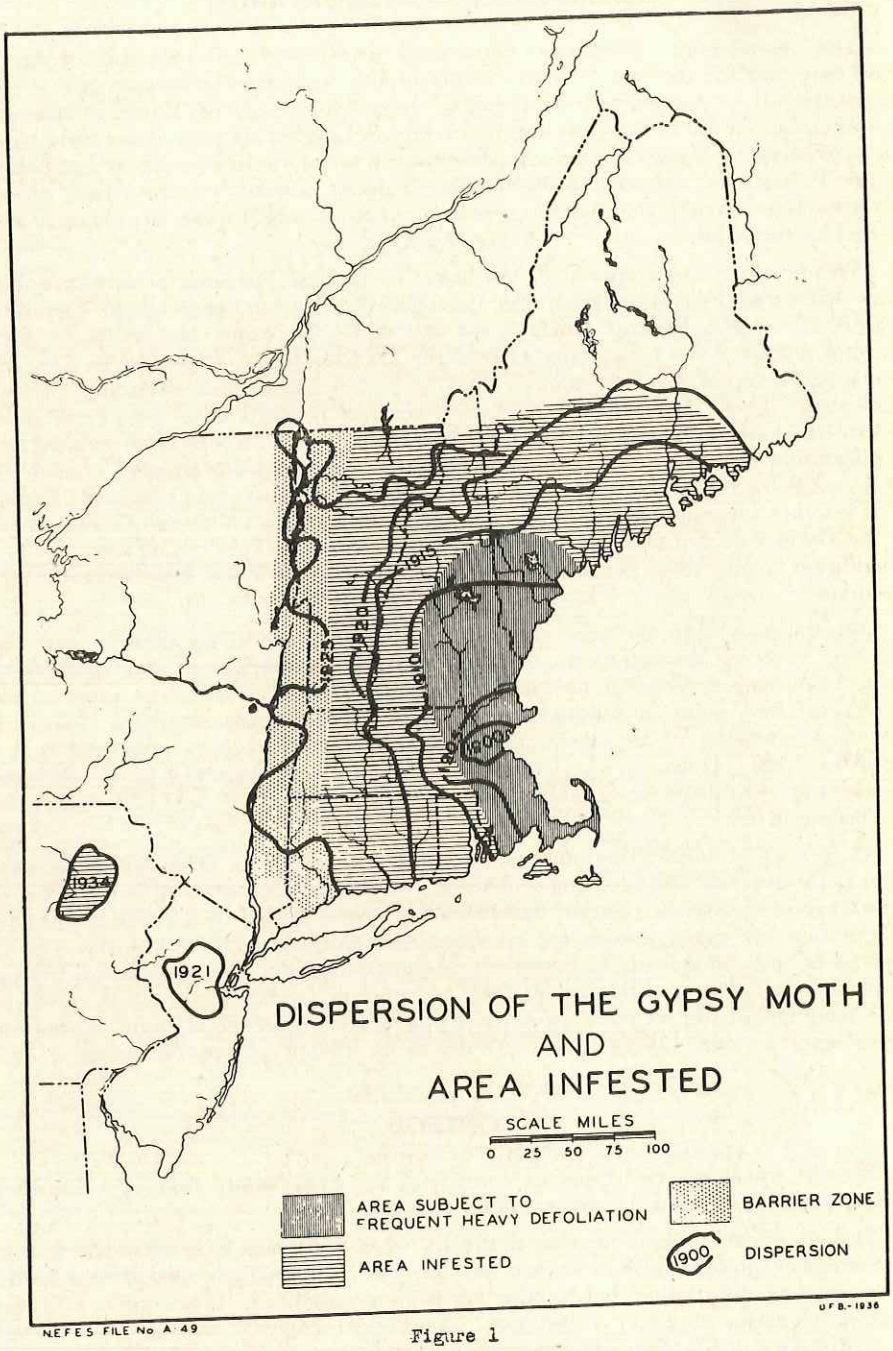
1925
1920
1915
1910
1905
1900
1934
1921
DISPERSION OF THE GYPSY MOTH
AND
AREA INFESTED
SCALE MILES
0 25 50 75 100
AREA SUBJECT TO FREQUENT HEAVY DEFOLIATION
AREA INFESTED
BARRIER ZONE
1900
DISPERSION
U.F.B.-1936
NEFES FILE No. A-49

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

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

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

(5) Species not favored in any larval stage —

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

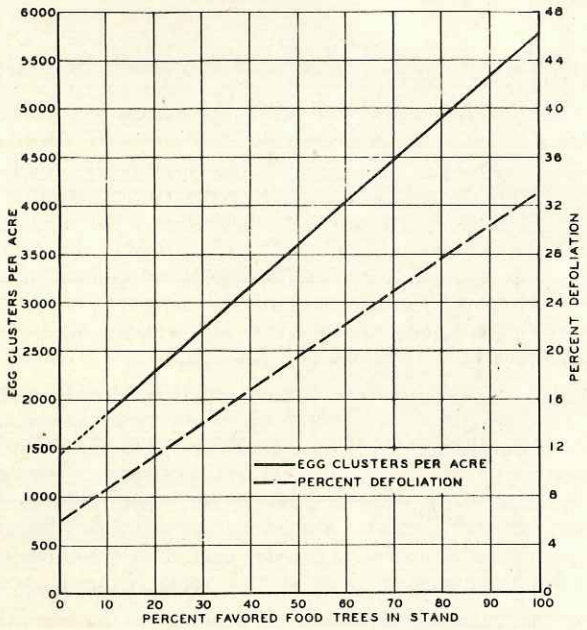

Figure 2.

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.

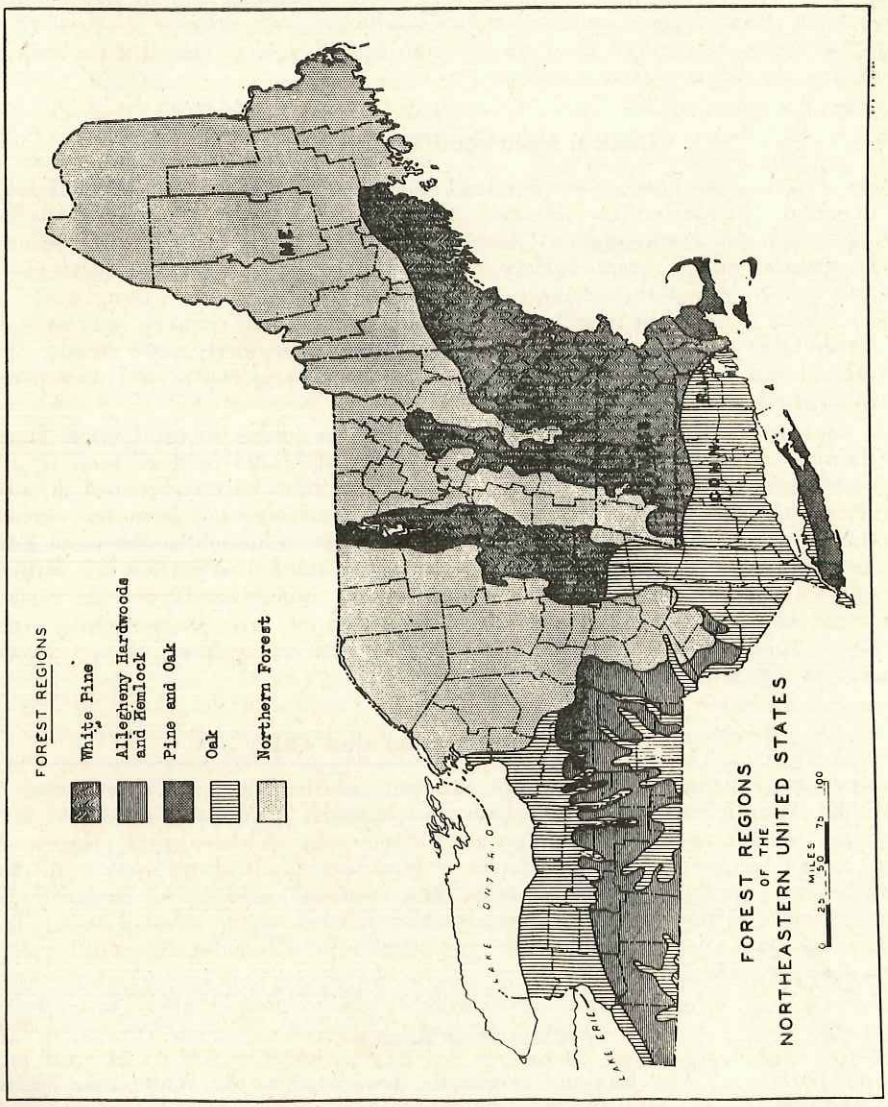

Figure 3

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.

Reprinted from JOURNAL OF FORESTRY
Vol. XXXIV, No. 8, August, 1936

A STUDY OF THE GYPSY MOTH IN THE TOWN OF PETERSHAM, MASS., IN 1935

BY W. L. BAKER AND A. C. CLINE

A STUDY OF THE GYPSY MOTH IN THE TOWN OF PETERSHAM, MASS., IN 1935[1]

By W. L. BAKER[2] and A. C. CLINE[3]

FOR many years the gypsy moth (*Porthetria dispar* L.) has been recognized as one of the most destructive forest-insect defoliators in the Northeast. Since it first attracted notice in Medford, Mass., 45 years ago, it has spread in all directions until at the present time a considerable portion of New England is infested. In 1923 a "barrier zone" from 25 to 30 miles wide was established in the western part of New England, from the Canadian border to Long Island Sound. In this zone the Bureau of Entomology and Plant Quarantine in cooperation with the New York State Department of Conservation has carried on an intensive eradication program to prevent the insect from spreading westward. A rigid quarantine to prevent the accidental carrying of the insect beyond the known infested areas has also been in effect for many years.

In some years in New England the number of acres defoliated, in varying degrees of intensity, has run into hundreds of thousands. The sections most seriously affected for many years are York and Cumberland Counties in Maine; Rockingham, Strafford, Hillsboro, Merrimack, Belknap, and Carroll Counties in New Hampshire; and Barnstable, Plymouth, and Bristol Counties in Massachusetts. There are, however, large areas east of the barrier zone where the insect has been present for many years but has never reached outbreak numbers. Observations have been made over a sufficient period, and over areas sufficiently large, to indicate that the insect can find conditions favorable for its increase to destructive numbers only in certain types of forest growth. It has long been known that it will thrive on the foliage of some species of trees, and will die where confined to the foliage of others. About 20 years ago data on feeding habits were collected and formed the basis for a table showing the various species of trees, grouped according to preference.[4]

Furthermore, the preference for certain types of foliage is not constant for all the larval instars. For example, oak foliage is desirable throughout the entire larval period, maple is not favored in any instar but will be fed on in the absence of more favored food, white pine is refused by the early instars but is very palatable to the larger larvae, while ash is refused by all instars. In cases of heavy defoliation in mixed stands composed of both favored and unfavored species, where there is sufficient favored food for the larvae to develop through the earlier instars the unfavored species are sometimes completely defoliated by the older larvae. This has given rise to the belief that any and all species are favored. The fact is that, unless some of the highly favored species are present in or near a stand of less favored species, no appreciable feeding on the latter will result. In New England those species highly favored by larvae of all ages are the oaks, poplar, gray birch, alder, willow, and apple.

The purpose of the present investiga-

[1]Paper presented before the Winter Meeting of the New England Section at Boston, February 20, 1936.

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[4]Mosher, F. H. Food plants of the gypsy moth in America. U. S. Dept. Agr. Bull. 250, 39 pp., illus. 1915.

tion was twofold: (1) to study the reactions of the insect to its food supply in an area never before heavily defoliated, in order to determine whether it had increased to outbreak numbers irrespective of food plants, or only in concentrations of favored food; and (2) to determine to what extent any discriminating food habits of the insect that might be discovered would permit the application of silvicultural measures of control in a particular locality.

Data bearing on this phase of the gypsy moth problem have been obtained over a number of years. In 1917 Clement and Munro[5] concluded that control could be effected by the removal of all the highly favored species from a stand. It was suspected then that the removal of only a portion of the favored trees would prevent injurious defoliation, but at that time there was not sufficient evidence to warrant definite recommendations. Much of the information that has been made available more recently was obtained from a large number of $^1/_5$-acre sample plots, established by the Federal Gypsy Moth Laboratory in 1911-12, distributed from southeastern Massachusetts to south-central New Hampshire and southwestern Maine and representative of a great variety of forest-cover types. Each tree over 3 inches in diameter breast high was individually observed and recorded by number. At first 264 plots were established, but after 10 years, owing to the death of trees due to defoliation, fire, cutting, etc., the number of useful plots was reduced to 104. Figure 1 shows the relation between the percentage of favored food trees in the plots and the intensity of infestation as measured both by egg masses and by defoliation. It is based on 104 plots and the 10-year period from 1912 to 1921.

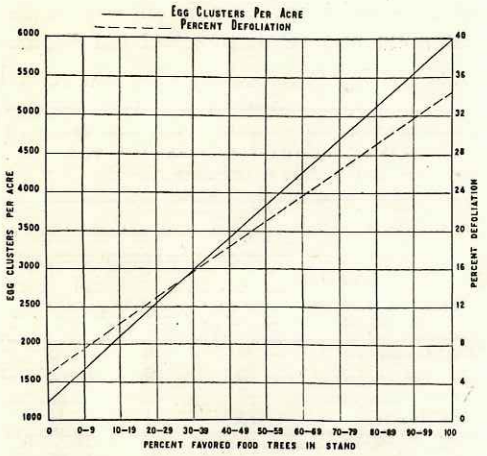

Fig. 1.—The relation between proportion of favored food plants in the stand and intensity of gypsy moth infestation and defoliation. Records from 104 woodland plots in various parts of the infested area in New England for the 10-year period 1912-1921.

This graph shows beyond reasonable doubt that the food supply is a controlling agent of the gypsy moth. The importance of this cannot be overemphasized. For one thing, it means that an enormous amount of mixed woodland growth may be infested but not seriously injured, and that it should be unnecessary to remove all favored food trees in such mixed growth to bring about adequate control.

Study of Outbreak at Petersham

Since silvicultural practice, as well as forest-cover type, varies in different localities, it is desirable from a forest-management standpoint to make intensive local observations, to serve as a basis for specific cutting plans for stand improvement. An exceptional opportunity for making such observations was offered in central Massachusetts in 1935, when the first epidemic outbreak of the insect occurred in that section.

[5]Clement, G. E., and Willis Munro. Control of the gypsy moth by forest management. U. S. Dept. Agr. Bull. 484, 54 pp., 1917.

Petersham was selected as the town for study, first because of its location with respect to the 1935 outbreak, and second because the Harvard Forest was situated within its boundaries. The study was started independently by the Harvard Forest, and concluded as a cooperative project of that institution and the Bureau of Entomology and Plant Quarantine.

Petersham proved to be an ideal town for studying the outbreaks, because of the nature of its forested land and its hilly terrain. It is characteristic of a considerable portion of north-central Massachusetts and the neighboring towns of southern New Hampshire. The rolling nature of the countryside made it possible to see every heavily defoliated (browned)[6] area in the town from one vantage point or another. Land history was such that many contrasting cover types were present, temporary as well as permanent, numerous small stands of favored food trees being intermingled with stands of strikingly different composition. A forest type map of the town, which covers about 22,000 acres, would show approximately 5,000 separate stands.

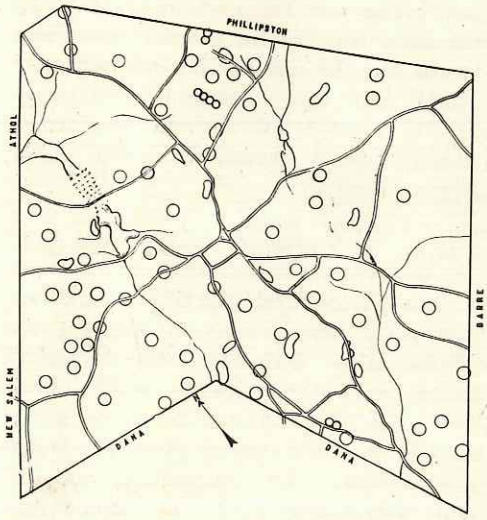

Fig. 2.—Areas in Petersham, Mass., defoliated by the gypsy moth in 1935.

The defoliated areas were located and plotted on a topographic map. (Fig. 2.) There were 82 such areas, and 81 of these were visited and studied by the authors. During the course of travel to and from these areas constant watch was kept for gypsy moth larvae, and invariably some were found wherever favored food trees were growing. This indicated that the insect was generally present throughout the entire town, although complete or nearly complete defoliation of the favored food occurred only in the 82 areas.

In these areas the stand composition and the average percentage defoliation of all species were determined by ocular estimation. It was impossible, and unnecessary from a practical standpoint, to measure these factors precisely, because the study had to be made within the 2-week period when defoliation was at its maximum and refoliation had not begun.

TABLE 1

OCCURRENCE OF CERTAIN TREE SPECIES IN HEAVILY DEFOLIATED AREAS IN THE TOWN OF PETERSHAM, 1935

Species or combinations of species in stand	Number of cases where species comprised indicated percentage range of stand		
	50-75 per cent	75-100 per cent	50-100 per cent
White oak	0	0	0
Red oak	2	0	2
Poplar (2 species)	8	4	12
Gray birch	13	21	34
Gray birch and poplar	18	39	57
Gray birch, oaks, and poplar	20	56	76
Gray birch, oaks, poplar, and alder			81

[6]Although certain individual trees in these areas, primarily those unfavored as food for the gypsy moth, were not completely defoliated, the general effect was a severe browning. From a distance such browned areas were strikingly different in appearance from their greener surroundings.

The data obtained from these areas are summarized in Table 1. They show that heavy defoliation was invariably associated with a high percentage of favored food trees in the stand.

The results show conclusively that concentrations of species favored as food by all larval instars accounted for the conspicuous defoliated areas in the town of Petersham. Complete defoliation was not observed in any instance where favored food trees constituted less than 50 per cent of the stand. In 56 out of the 81 defoliated areas oak, gray birch, and poplar comprised more than 75 per cent of the stand, thus showing the importance of these three species in creating a suitable environment for the gypsy moth.

Invariably it was observed that the heavy defoliation was limited to stands or portions of stands composed wholly or largely of favored food trees, and that it ceased abruptly with changes in composition of adjoining stands. In addition to the information from the 81 defoliated areas, data were also obtained from the lightly defoliated margins of some of the adjoining stands. A comparison of composition and defoliation under the two conditions is shown for 12 cases in Table 2. Marked differences in composition are at once evident. Favored food trees comprised an average of 89.5 per cent of the defoliated stands, but only 19.3 per cent of the margin of the adjoining stands. The little defoliation that occurred in the latter was limited to a narrow margin, evidently due largely to migrants from the defoliated stand of favored trees. In several cases where narrow strips of unfavored species separated heavily defoliated stands of favored species, the former showed only a trace of feeding—further proof of the discriminating feeding habits of the moth.

Recommendations for Control Program

The findings of this study in the Petersham area, taken into consideration with defoliation records and experiments on host preference over a period of years, warrant the following specific recommendations for the control of the gypsy moth

Table 2

Comparison of defoliated stands with the margins of adjoining stands

	Average percentage of favored foods		Average percentage of defoliation					
			—Favored food—		—Unfavored food—		—All trees—	
Plot No.	Defoliated area	Margin of adjoining stand	Defoliated area	Margin of adjoining stand[1]	Defoliated area	Margin of adjoining stand	Defoliated area	Margin of adjoining stand
11	86	12	87	33	37	5	80	9
16	86	21	91	91	58	11	86	28
24	87	15	100	24	54	6	94	8
38	92	19	100	10	47	0	96	2
39	95	1	100	0	100	0	100	0
40	97	32	85	44	75	6	84	18
41B (NE)	91	10	99	36	50	17	95	19
41B (W)	91	16	99	37	50	15	95	17
42	90	51	96	26	34	3	90	14
51	91	35	100	14	72	9	98	11
71	83	5	100	100	54	11	92	15
72	87	15	87	8	55	5	83	6
Mean	89.7	19.3	95.3	35.3	57.2	7.3	91.1	12.2

[1]In certain plots, notably nos. 16 and 71, where favored food trees in the margins of adjoining stands suffered heavily from defoliation, it was due to scarcity of these trees in the composition and their greater occurrence at the extreme edge of the margin next to the defoliated area.

through a program of silvicultural treatment, where conditions are similar to those in Petersham.

Coniferous Plantations.—As previously stated, the older larvae find coniferous foliage a desirable food. Since conifers, with the exception of larch, lack the ability to refoliate following complete defoliation, and since plantations represent a comparatively large investment in new growing stock, the protection of plantations of conifers is placed first on the list of priorities in treatment.

In Petersham both gray birch and poplar commonly seed into old fields and pastures, either before or after plantations are established. On cut-over lands these species are often supplemented by sprouts of red and white oak. The newly hatched caterpillars are able to develop on any and all of these hardwood species. Following complete defoliation the larvae, if they have reached the third instar, can easily migrate to the conifers and defoliate them. Thorough clearing of the planting site prior to planting and timely weeding thereafter will serve the needs of both silviculture and protection. Severe damage to coniferous plantations is usually due to neglect to weed. Nothing is to be gained in any event by allowing a good plantation to be whipped and suppressed by overtopping hardwoods of little or no value, and not intended as part of the crop. It is true, of course, that a hardwood "filler" has proved advantageous in improving the quality of conifers, but in a properly managed stand such a filler is kept below the conifers and not above. Even so, where it is made up largely of gray birch, it may be advisable to remove it. Loss of quality in the butt log is of less importance than defoliation of the tree.

Underplantings. — Underplanting has been used very little locally, but where it has, conditions are usually favorable for moth attack. This is because gray birch and poplar are among the species commonly thought suitable for an overstory. Here the treatment is plainly one of cutting the birch or poplar overstory, even though it may be furnishing protection to the conifers against the white pine weevil and may be too small to make cordwood. Conifers growing directly beneath a canopy of favored food trees are liable to be seriously defoliated. At the same time, it is recognized that sudden and complete release from partial suppression may result in damage to the conifers from snow or ice. In some cases releasing may require two steps, the first one reducing favored-food-tree foliage as much as possible without jeopardizing reasonable security against bending and breaking with snow or ice loads, with the final removal cutting a few years later, when the conifers have strengthened their stems sufficiently to withstand the elements.

Coniferous Understories of Natural Origin.—From the standpoint of control, conditions here are much the same as those discussed under "Underplantings". Frequently pine and gray birch seed simultaneously into old fields and pastures, but the birch soon overtops the more slowly growing pine, arrests its growth by whipping off the buds, and in time often completely suppresses it. The obvious treatment is the cutting of the birch before suppression of the pine has reached a critical stage, and before a moth colony becomes established.

Almost without exception, both coniferous plantations and natural coniferous reproduction, whether on old fields or cut-over land, contain more or less weed hardwoods of the favored food species, and their prompt elimination is demanded both as sound silvicultural practice and as a protective measure.

Isolation Strips.—Several cases of defoliation were observed at the margins of coniferous plantations growing next to stands composed wholly or largely of gray birch, poplar, alder, or oak. It is

evident that the removal of favored food trees from within plantations or young coniferous stands of natural origin must be supplemented by cutting a protective strip wherever such hardwoods occupy adjoining areas. On the basis of several observations, it would seem that, under conditions at Petersham, a cleared strip about 100 feet wide should be sufficient to prevent any serious defoliation along the margin of the coniferous stand.

Mixed Stands of Pine and Better Hardwood.—In a few cases noted, some defoliation of pine occurred because of its association with red and white oak. Such mixtures are found on the lighter soils, or on exposed southern slopes and ridge tops. It is not a common condition in Petersham. In middle-aged or maturing stands of this composition, the pines generally were not defoliated to such an extent that they would die, except perhaps where they formed a minor element in the mixture. In some cases, however, defoliation might be severe enough to warrant protective treatment, and this would take the form of a cutting to reduce the quantity of oak foliage. It is believed that a reduction to about one-half that of the pine will assure safety of the latter from heavy defoliation, but further observations are needed on this point. Where conditions of ownership and merchantability warrant the complete elimination of the oak, any sizeable opening made by cutting might be planted to conifers, thus forming a groupwise coniferous mixture of two or more age classes.

On the Harvard Forest, young groupwise mixtures of conifers and better hardwoods, including in some instances a substantial proportion of red oak, may require protective treatment. Since, on the heavy soils where such mixtures are being developed, there is a large variety of hardwoods available for the crop, the treatment will consist of a reduction in the proportion of oak and a corresponding increase in that of such species as white ash, hard maple, and paper birch. This alteration in composition can be done in the course of weedings and improvement cuttings regularly carried out in such stands. It is probable that reduction of oak foliage to somewhat less than half the total for all hardwoods in a given group will afford adequate security to the neighboring coniferous group. Because of the strong tendency of red oak to crowd out other valuable hardwood species, a reduction in the proportion of this species, especially through cutting the coarser individuals, is considered desirable from the standpoints of high-quality crop production and a well-balanced mixture, regardless of its protective value.

Stands of Mixed Better Hardwoods.—With a few exceptions such stands in the town of Petersham fall within the so-called Transition Hardwoods type, which is composed of a considerable variety of commercial species representative of both the Northern Forest and the Central Hardwood Forest. Since the death of chestnut, however, red oak is the most aggressive species in the mixture, and in many stands of middle age or older it predominates to the extent of occupying a larger proportion of the crown canopy than all associated species combined. For the most part the latter are unfavored food species. To avoid recurrent defoliation of the oak, particularly where it occurs in groups, with at least a resultant slowing down in growth, some alteration in stand composition is indicated. Under local conditions it is believed that a reduction in the volume of oak and other favored foliage to an upper limit of one-half of the total for the main canopy will afford satisfactory protection. Depending upon age, density, and relative proportions of favored and unfavored species, such a reduction will require one or more cuttings annually over a period of years. These may well be combined

with the ordinary types of improvement cuttings and thinnings applicable to such stands.

Stands of Favored Weed Species.—Stands of gray birch or poplar, or mixtures of the two, occur commonly throughout the town. As shown in Tables 1 and 2, these provided the chief sources of infestation. Though neither species is sufficiently valuable to warrant much concern over its protection, there are places where the owner may wish to avoid further trouble. Plainly the only possible method of silvicultural control is clear-cutting followed by planting. On the best soils hardwoods of unfavored species or mixtures of such hardwoods and conifers may be used; on the lighter soils, conifers alone. Such complete conversion from weed hardwoods to valuable saw-timber species is, of course, a part of the usual plan of management on the organized forests.

The conditions cited above are the ones commonly found in Petersham. They are by no means representative of the entire region infested by the gypsy moth. It is believed, however, that measures of indirect control through silvicultural treatment must be worked out locally, and that the observations of the past season in this town and the conclusions drawn therefrom contribute toward this end.