

# The progression of a gypsy moth invasion of a mature oak forest in New Jersey

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**Abstract.** The gypsy moth is the principal defoliating insect pest of the hardwood forests of the northeastern United States. The history of its spread in New Jersey and of efforts to control it are briefly reviewed. First discovered in Hutcheson Memorial Forest in 1971, its population has since been monitored yearly by means of egg mass or larval counts. The population increased ten-fold from 1973 to 1974, but collapsed prematurely as a result of an epizootic early in June 1974. Since then the population appears to have stabilized at a low density as a result of increasing parasitism and perhaps reduced reproductive vigor. Overall defoliation has not exceeded 20% in the five years of this study.

Given the history of dramatic cyclic changes in abundance in other populations, it is likely that sometime in the future the gypsy moth will increase in Hutcheson Memorial Forest to epidemic proportions. In such an event, significant mortality of oaks is expected. It is predicted that this could reduce the relative basal area of white oaks by 70%, thin their density by 90% and open the present closed canopy by at least 50%. With maples and beech being essentially unaffected by defoliation, this would provide a further impetus to the successional drift of the forest away from an oak disclimax.

The gypsy moth (*Lymantria dispar*) is indigenous to the temperate latitudes of Europe, Asia, and Africa. It was accidentally released into North America in 1869 at Medford, Massachusetts, and over the last century has spread north to the Canadian border, west almost to Ohio, and south to parts of Delaware and Maryland (USDA, 1977).

Populations of gypsy moths spread naturally via wind-blown dispersal of first-instar larvae. Under some circumstances they are known to have been carried in this way for 20 miles (Collins, 1917). In North America this process has been aided at times by the inadvertent transport of egg masses attached to vehicles, building material or any other movable object. By the latter means, two early outbreaks occurred in New Jersey, both from importation of nursery stock. A small population in 1914 at Rutherford was eradicated in a year from a half-acre area. In 1920 a local population was found at the Duke Estate, near Somerville, probably originating from egg masses brought in with stock from Holland in 1911. A survey revealed that the moth was distributed over 410 square miles, 175 of which were generally infested. It required 10 years and 2 million dollars to eradicate the population. This was accomplished by creosoting the egg masses, spraying with lead arsenate, and applying sticky-tar tree bands (Weiss, 1922).

The principal immigration of the gypsy moth into New Jersey came via southward dispersion from the Massachusetts epicenter, entering the state on a broad front across the New York border around 1954. Initially, this was countered by the state with an eradication program using DDT at a rate of 1 lb./acre. Over the next 9 years, 450,000 acres of woodlands in Sussex, Passaic, Bergen, Morris and Warren counties were treated in this manner. It has been reported that DDT did eradicate the gypsy moth in the local areas over which it was

applied (Nichols, 1961). However in the early 1960's, reinfestation followed rapidly from nearby untreated areas in New York. By 1963 the wisdom of widespread use of DDT had become a serious issue in light of the newly recognized environmental side-effects it produced. After DDT was phased out in 1964, it soon became evident that the less persistent substitute insecticide employed (Sevin) could not prevent some dispersion or yield the complete or near-complete kills necessary for eradication. This approach was therefore abandoned in 1965, and in its place a policy of protecting foliage and retarding heavy dispersion was adopted. For the first time, not all known infestations were treated regardless of their magnitude. (Fringer, R.C. Unpublished report, N.J. Dept. of Agric., undated.) By 1967 the gypsy moth had spread to the southernmost counties in New Jersey, and the northern counties contained high density populations. In 1976, defoliation was concentrated in the central part of the state (scattered throughout Middlesex and Monmouth Co's.) and over extensive areas in Cape May County. The suppression policy has now evolved to one in which foliage protection is provided for undeveloped areas of high aesthetic value (e.g. state forests and parks) and extensively wooded residential areas. In conjunction with this chemical-control approach, heavy emphasis is being placed on the parasite rearing and release program begun in 1963.

The gypsy moth must now be considered as a firmly established species in New Jersey, as it is in most states in the northeastern United States. As it integrates with the existing insect community, the dramatic widespread outbreaks of defoliation which characterized it as an invader species can be expected to decline. If it follows the patterns of the past in New England and in its native lands, its populations should only occasionally reach pest proportions in certain areas, as do even some of our native forest moths.

The invasion of the tri-state area is virtually complete, but there are vast areas of suitable habitat to the south and west which are vulnerable to gypsy moth attack. It is estimated that these cover 100 million acres, a significant amount of which is in the commercially valuable timber lands of the southern Appalachians. There will undoubtedly be heavy pressure to provide foliage protection or perhaps eradication with insecticides to prevent the heavy tree mortality which often results from severe defoliation. (In 1974, North Carolina petitioned the Environmental Protection Agency to suspend the ban on DDT to enable its use to eradicate the first small population of gypsy moths to invade the state. The petition was later withdrawn.) Large-scale broadcasts of even non-persistent insecticides have a potential for severe ecological disruption in insect communities and perhaps indirectly in other communities (Moulding, 1976). However, uncontrolled defoliation might be an equally disruptive force in that extensive tree mortality radically alters the

habitat. To investigate this and other questions dealing with the effects of an uncontrolled gypsy moth infestation, it was desirable to study a forest which had not suffered significant insect damage in the past, was presently being invaded by the gypsy moth, and was by nature of its vegetative structure and species composition vulnerable to heavy defoliation damage. Hutcheson Memorial Forest (HMF) in East Millstone (Somerset County), New Jersey was an ideal site in these regards.

This paper reports on the progression of the gypsy moth invasion of this 65-acre mature oak forest over a period of five years, and discusses potential future events and their consequences.

### Methods

Population densities of gypsy moths can most readily be monitored by making egg mass counts. Females oviposit in clusters or masses containing an average of 400 eggs. The egg masses are round to oval in shape averaging about 1" in diameter and covered with buff-colored hairs from the insect's abdomen. They resemble small pieces of chamois attached primarily to the boles and underside of large branches of trees, particularly oaks of the white oak groups. Oviposition sites are usually cryptic in low-density populations, but become increasingly less so as density increases.

Evidence of gypsy moth presence in HMF was first discovered in late 1971, with scattered egg masses found primarily behind posted signs along the perimeter of the forest. A methodology for egg mass surveys was developed and standardized for the 1972 and subsequent counts: 17 regularly spaced stations were established throughout the major undisturbed part of the forest. These were located at corner stakes of the existing 100 m grid within the forest (Figure 1). A 1/10-acre circle (ra-

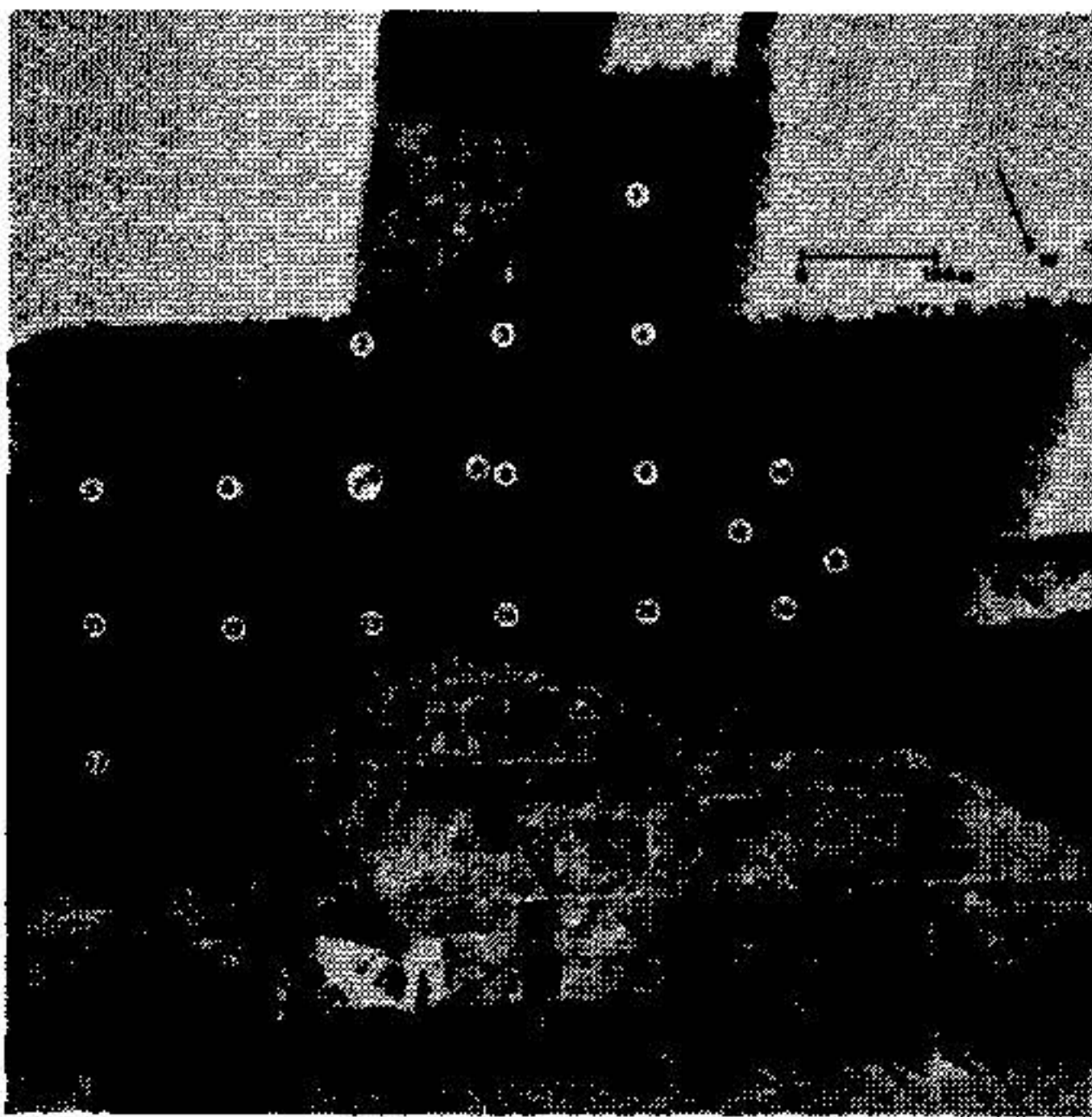


Figure 1. Locations of gypsy moth population sampling stations; UV light traps = \*. (Aerial photography flown 9 February 1976).

dius = 37.2') was described around each stake. Egg-mass counts were made by visually scanning all canopy trees that had their boles on or within the circle. Binocu-

lars (8x) were used to search the upper branches. The species and diameter at breast height (dbh) of each canopy tree in the circle was recorded along with the number of egg masses on it. Initially, understory trees and fallen logs were also searched, but this was discontinued as unnecessarily time-consuming since the counts were generally found to be consistent with those on canopy trees and did not add appreciably to the total tally. It was apparent after the study had begun that a chance absence of white oak within the circle seriously biased downward the density estimate for the vicinity. At these four stations, the two (average of the other 13 stations) nearest outside white oaks were included in the counts. Egg mass surveys were conducted in November shortly after leaf-fall. At this time, the tan egg masses are more visible and less easily confused with the weathered gray masses from the previous year. However, after several years I became increasingly less confident of separating new oviposition from old. This was particularly difficult in HMF since many of the egg masses were on the undersides of large branches, 60 ft. or more high. Also the tendency to oviposit on the north sides of trees resulted in unfavorable lighting for distinguishing shades of color. In the summer of 1975, therefore, caterpillar counts were adopted in place of egg mass counts. At each of the census stations, a 9" folded strip of burlap was tied around the white oak which had previously had the highest egg mass count. This method took advantage of the behavior of late-instar larvae of descending the boles of host trees during the day to find protected resting sites, and then ascending to feed at night. (Under high population density conditions, however, the caterpillars stay in the canopy, feeding continuously.) Caterpillars which congregated beneath the folds were counted once or twice a week from mid-June to mid-July. The larvae were tallied by instar and each was examined for signs of parasitism by a tachinid fly (*Parasetigena silvestris*) as evidenced by a small white egg adhering to the dorsal surface. Instars were differentiated by the proportionate size of the head capsule. Additional information on gypsy moth populations was obtained from catches of adult males in four 6-watt UV light traps which were operated at permanent sampling stations one night a week during the summer, starting in July 1973 (Figure 1).

Parasitism in 1976 was additionally assessed on 4 August by a survey of pupae beneath the burlap strips. By this time, all gypsy moths had either emerged as adults or succumbed. In the former case, the pupal casts were split along the antennal suture. Parasitized pupae showed an emergence hole which was broadly characteristic of the type of parasite. The chalcid wasp parasite, *Brachymeria intermedia*, which oviposits directly into pupae, emerges through a small, round hole usually on the head or thorax. Tachinid fly larval parasites emerge from pupae through an oblong hole on the thorax or between abdominal segments. Ichneumonid wasp emergence holes are round and jagged. Predation by the carabid beetle, *Calosoma* spp., is evidenced by a large irregular hole. Each of the above categories was also tallied by sex, as determined by examining the ventral

surface of the last abdominal segment for evidence of a longitudinal depression. This is absent in males.

All botanical nomenclature used is according to Fernald (1950).

### Results and Discussion

The results of the population surveys at each sampling station for the past four years are shown in Table 1.

Table 1. Comparison of population density among years as indicated by egg mass or larval counts at fixed sampling stations.

| Station           | Egg Masses / Acre <sup>a</sup> |      |      | Maximum count<br>Larvae + Pupae |      |
|-------------------|--------------------------------|------|------|---------------------------------|------|
|                   | 1972                           | 1973 | 1974 | 1975                            | 1976 |
| 1                 | -                              | 1430 | 1480 | 34                              | 88   |
| 2                 | 70                             | 410  | 210  | -                               | -    |
| 3                 | 430                            | 5460 | 3000 | -                               | -    |
| 4                 | 80                             | 1080 | 890  | 41                              | 54   |
| 5                 | 10                             | 500  | 230  | 67                              | 28   |
| 6                 | 0                              | 680  | 770  | 82                              | 32   |
| 7                 | 50                             | 130  | 80   | 77                              | 41   |
| 8                 | 510                            | 1210 | 2120 | 46                              | 69   |
| 9                 | 600                            | 5220 | 1610 | 56                              | 22   |
| 10                | 10                             | 1480 | 860  | 61                              | 144  |
| 11                | 10                             | 100  | 160  | 124                             | 28   |
| 12                | 30                             | 690  | 480  | 56                              | 25   |
| 13                | 60                             | 1050 | 1320 | -                               | -    |
| 14                | 10                             | 80   | 540  | -                               | -    |
| 15                | 20                             | 1140 | 1540 | 66                              | 107  |
| 16                | 100                            | 1590 | 350  | 76                              | 42   |
| 17                | 0                              | 200  | 240  | 105                             | 35   |
| Ave.              | 124                            | 1321 | 934  | 68.5                            | 55.0 |
| C.V. <sup>b</sup> | 160%                           | 121% | 36%  | 37%                             | 68%  |

a-The gypsy moth has one generation a year, the eggs being the over-wintering stage (see Fig. 2). The egg mass count for a particular year, therefore, is proportional to the starting population for the following year.

b-coefficient of variation

Since the gypsy moth is univoltine and the eggs are the over-wintering stage (see Figure 2), the egg mass count in a particular year is proportional to the starting population for the following year. Larval counts and egg mass counts cannot be directly compared. The latter is an absolute measure of starting population density, assuming constant egg parasitism and fecundity (probably valid in a growing population). Larval counts, on the other hand, represent a sample of the population on a tree after dispersion and some mortality has occurred. Not all caterpillars on the tree may descend each day to the burlap before finding resting sites. Also, judging from egg mass placement, considerable pupation occurs on the upper branches, since females are flightless and therefore oviposit at the pupation site.

The 1973 egg mass data clearly show the rapid ten-

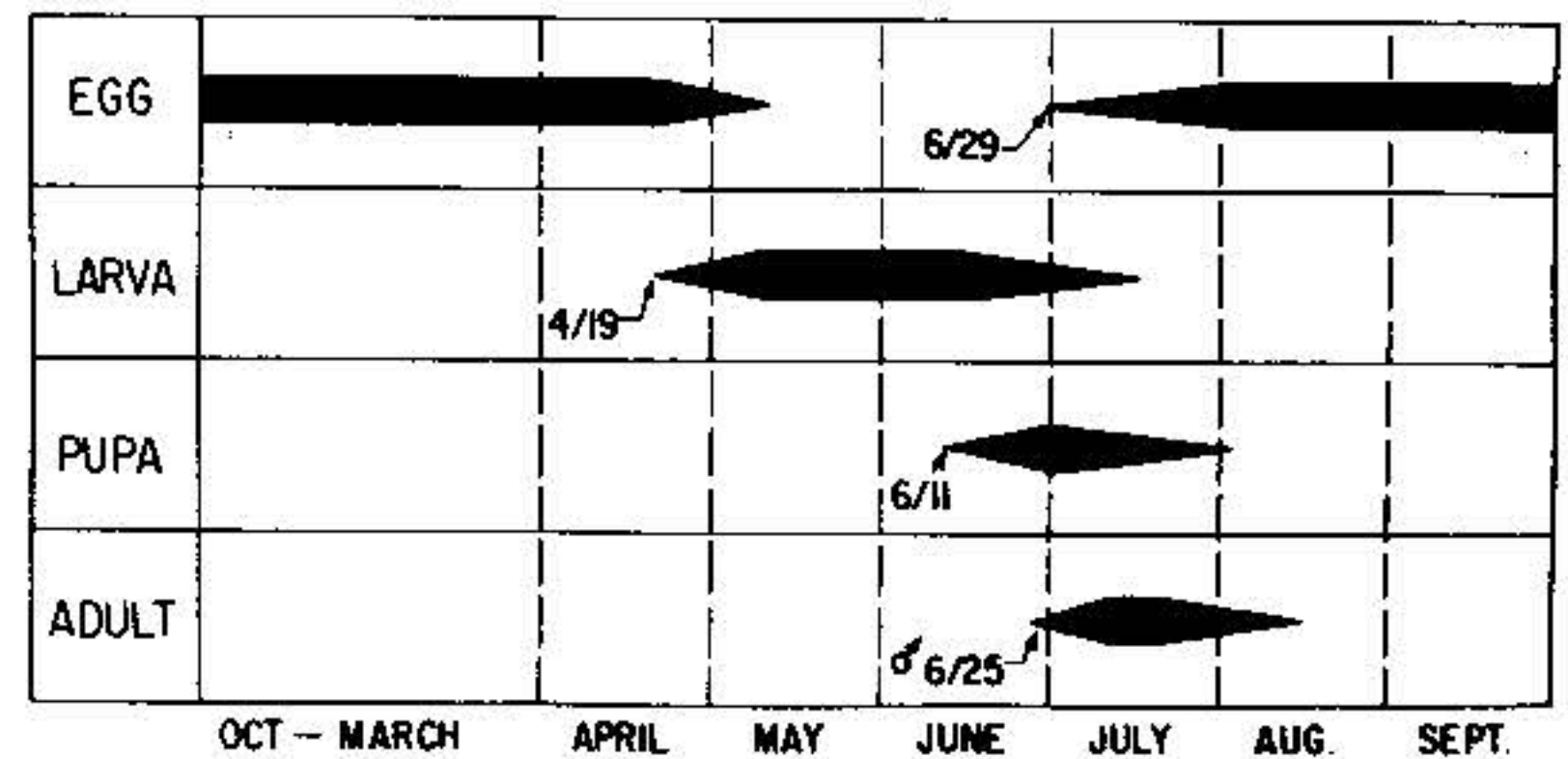


Figure 2. Seasonality of the life stages of gypsy moth in HMF. The earliest recorded onset date of each stage is indicated. (The timing and length are somewhat dependent upon weather and food availability.)

fold buildup in population density in one generation. This is very characteristic of gypsy moths during the early stages of an invasion of suitable habitat. Defoliation by late June 1973 was estimated from aerial photographs to be between 10 and 15% overall, and fairly evenly distributed. When egg mass counts approach 300/acre, 75% defoliation of oak forests can be expected. Based on this and the egg mass production of the 1973 generation, a heavy and extensive defoliation of oaks was predicted for 1974. This prediction appeared to be valid in early June 1974 as moderate to heavy larval frass (feces) fall was observed over most areas. However, there was an unexpected decrease during the second and third week of June—a time when larvae would have reached the last two instars, and 70% (Ahmad, S., and A.J. Forgash, 1975, unpublished data) of the defoliation normally occurs. Aerial reconnaissance in late June revealed that overall defoliation again did not exceed 20%, with only a few trees completely stripped. Defoliation was unevenly distributed; the northeastern end of the forest, in particular, received almost no damage.

A decline of this magnitude almost certainly can be attributed to an increase in incidence of "wilt disease" in the population. This is a wasting disease caused by a nuclear-polyhedrosis virus (*Borrelinavirus reprimens*) which is always present in gypsy moth populations, but usually increases in virulence only when larval susceptibility is increased by some physiological stress. It is the ultimate causative factor in the natural collapse of an infestation when population growth exceeds the carrying capacity of the food resource. Since food stress was certainly not present in HMF, it is postulated that some environmental, probably meteorological, factors caused a controlling increase in incidence of wilt disease in the population. Credence is lent to this explanation by the fact that there were a great many unexpected population declines that summer throughout most of the northeast, Maine and Massachusetts excepted (USDA, 1977). This is clearly shown in the trend of defoliation in New Jersey over the past ten years (Figure 3). Although meteorological influence has been cited as contributory to help explain the widespread nature of the phenomenon, no simple pattern appears from an examination of temperature and rainfall records at HMF over the period (Table 2). A comparative analysis of daily weather events during the principal larval growth period from mid-May to

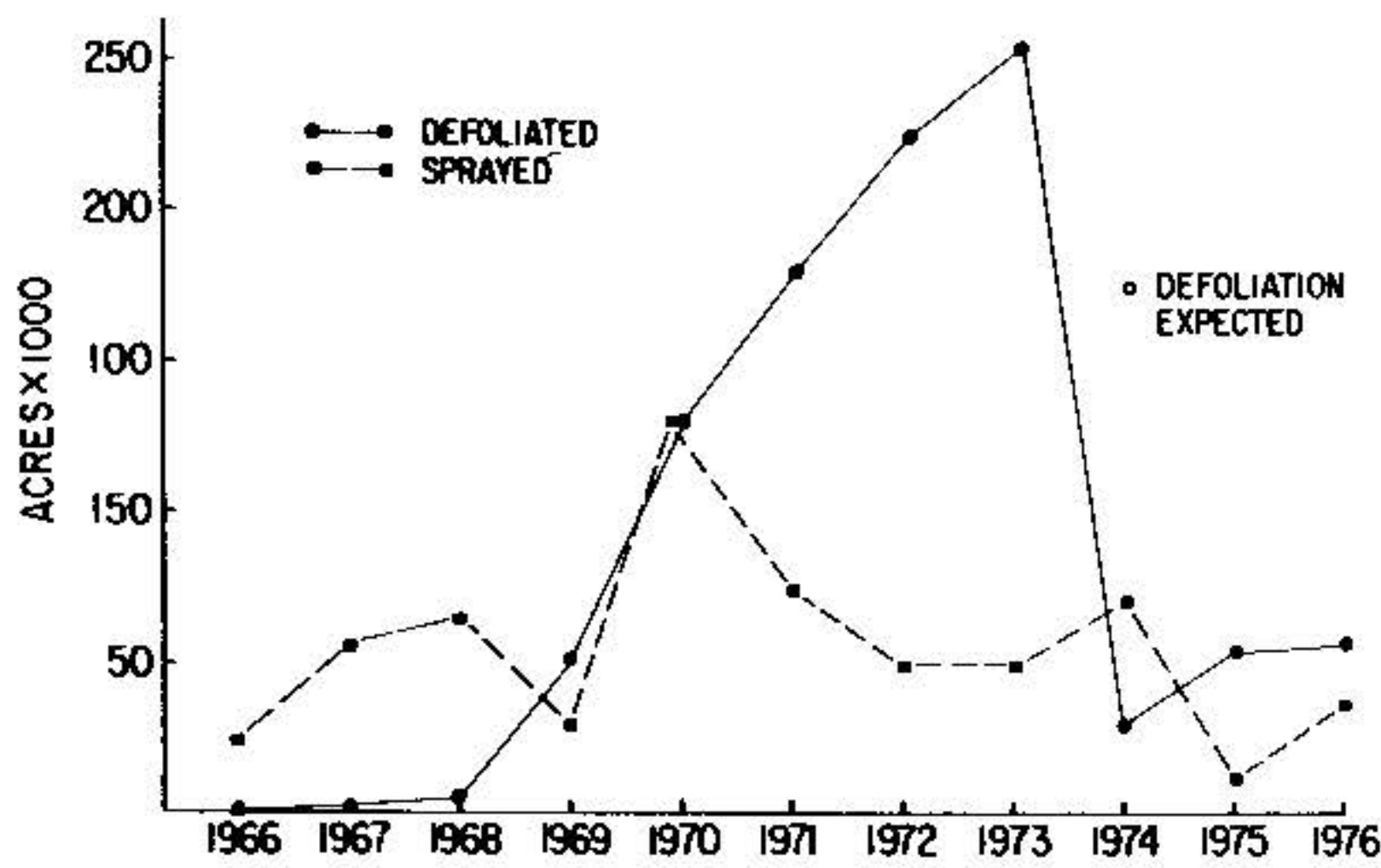


Figure 3. The trends in gypsy moth defoliation and suppression in N.J. (Fringer, R.C., N.J. Dept. of Agr., pers. comm.)

mid-June showed that the monthly summary presented is representative of this period also.

Although light-trap catches of male moths in 1974 indicated that the population density was considerably lower than in 1973 (Table 3), the egg mass survey conducted during the fall of 1974 suggested that population resurgence might have occurred. Infra-red photographs taken aerially on 2 July 1975, however, revealed that overall defoliation again did not exceed 10-15%. This supports the suspicion that the 1974 survey was inflated by accidental re-counts of old egg masses. By 1976 it was evident that at least over the short term, no major population expansion was taking place.

The larval and pupal surveys conducted during 1975 and 1976 indicated that the rate of parasitism was rapidly increasing in the population and was probably a major cause of mortality (Table 4). Parasitism almost inevitably causes the death of the host at about the time the parasite emerges, and in the case of larval parasitism,

the caterpillar usually stops feeding one or two weeks before death. The most reliably quantifiable parasite is *Parasetigena silvestris* (Diptera, Tachinidae), a generalist which attacks late-instar larvae. A four-fold increase in abundance of this species was observed over the last year. Another tachinid fly, *Compsilura concinnata*, lays a living maggot inside the caterpillar. Its presence could not be directly verified; however, since it is widely established in the state and has over 200 alternate hosts, its presence was likely. The pupal parasite, *Brachymeria intermedia* (Hymenoptera, Chalcidae) was observed at the burlap sites, but could have played only a minor role since no pupal emergence holes were found. Leaf-rollers (Lepidoptera, Tortricidae) are thought to serve as alternate hosts. *Brachymeria* could be expected to assume greater importance if gypsy moth population density increases in the future. It has been found to be most effective in heavy infestations where there is increased penetration of light through the defoliated canopy (W.C. Metterhouse, N.J. Dept. of Agr., pers. comm.). Pupal parasitism is particularly important since it acts on the last host stage before reproduction. Two species of wasps were observed which are specialists on gypsy moth. *Apanteles melanoscelus* (Braconidae) attacks early instar larvae. An average of 2.5 cocoons of this species were noted beneath the burlap strips in 1976. An egg parasite, *Ooencyrtus kuwanae* (Encyrtidae), had been observed ovipositing in egg masses since 1971. Its very small size (1/16") usually precludes it from parasitizing more than the top layer of eggs in the mass (10-15%). This may increase, however, to 70-80% when reduced vigor results in smaller egg masses, as was observed at HMF in 1975.

All of these parasites have been imported from Europe and Asia during the past fifty years, and have since become established in the Northeast. Those with

Table 2. Yearly comparisons of monthly rainfall and temperature recorded at Hutcheson Memorial Forest

| Month     | Mean Daily Temperature (°F) |      |      |      |      |      |                 | Rainfall (in.) |       |       |       |       |       |                 |
|-----------|-----------------------------|------|------|------|------|------|-----------------|----------------|-------|-------|-------|-------|-------|-----------------|
|           | 1971                        | 1972 | 1973 | 1974 | 1975 | 1976 | 30 yr.*<br>ave. | 1971           | 1972  | 1973  | 1974  | 1975  | 1976  | 30 yr.*<br>ave. |
| January   | 25.6                        | 31.7 | 32.8 | 32.2 | 33.8 | 24.0 | 29.8            | 3.90           | 1.81  | 4.61  | 6.03  | 5.57  | 5.28  | 2.88            |
| February  | 32.5                        | 27.4 | 30.1 | 29.2 | 32.8 | 35.4 | 31.5            | 8.01           | 4.26  | 4.42  | 4.08  | 3.52  | 2.71  | 2.80            |
| March     | 38.8                        | 37.8 | 43.9 | 39.8 | 37.6 | 42.9 | 39.7            | 3.18           | 3.83  | 3.35  | 5.83  | 3.59  | 2.35  | 3.86            |
| April     | 47.8                        | 46.6 | 51.8 | 51.7 | 45.0 | 52.2 | 50.9            | 3.78           | 2.74  | 5.90  | 3.21  | 2.98  | 1.84  | 3.51            |
| May       | 58.1                        | 59.4 | 57.2 | 59.0 | 62.8 | 59.1 | 60.9            | 3.10           | 4.61  | 4.79  | 3.86  | 5.37  | 4.01  | 3.72            |
| June      | 69.8                        | 65.0 | 72.2 | 66.0 | 68.9 | 71.2 | 70.0            | 1.80           | 8.28  | 4.93  | 2.81  | 5.96  | 2.83  | 3.37            |
| July      | 72.7                        | 74.1 | 74.3 | 73.2 | 75.8 | 71.0 | 74.5            | 7.22           | 5.20  | 2.24  | 1.80  | 15.98 | 3.47  | 4.80            |
| August    | 71.2                        | 71.2 | 74.0 | 72.7 | 72.3 | 71.0 | 72.8            | 13.41          | 0.26  | 7.47  | 8.80  | 3.68  | 3.07  | 4.74            |
| September | 68.1                        | 66.8 | 65.3 | 64.1 | 61.2 | 62.2 | 66.1            | 6.60           | 0.59  | 3.93  | 5.51  | 9.08  | 1.24  | 3.38            |
| October   | 59.6                        | 49.4 | 55.0 | 50.0 | 57.4 | 48.7 | 55.3            | 2.95           | 5.84  | 4.55  | 2.49  | 4.23  | 6.04  | 2.94            |
| November  | 42.2                        | 42.1 | 45.2 | 44.5 | 48.3 | 38.0 | 44.1            | 4.26           | 7.71  | 1.31  | 1.60  | 3.69  | 0.38  | 3.80            |
| December  | 37.8                        | 36.8 | 36.4 | 36.0 | 33.8 | 27.5 | 32.5            | 1.08           | 4.97  | 9.04  | 5.53  | 2.82  | 2.24  | 3.59            |
| Annual    | 52.0                        | 50.7 | 53.2 | 51.5 | 52.5 | 50.3 | 52.3            | 59.29          | 50.10 | 56.54 | 51.55 | 66.47 | 35.46 | 43.39           |

\* 1941-1970; Reporting Station: Somerville, 8 mi. NW of HMF

Table 3. Yearly comparison of catches of male gypsy moths in light-traps at fixed sampling stations.

| Trap # | 1973 | 1974 | 1975 | 1976 |
|--------|------|------|------|------|
| 1      | 62   | 24   | 9    | 16   |
| 2*     | 40   | 5    | 2    | 6    |
| 3*     | 52   | 8    | 4    | 24   |
| 4      | 22   | 35   | 12   | 16   |
| Totals | 176  | 72   | 27   | 62   |

\*Except for 1973, these traps were 60 ft. up in the canopy; all other traps were 6 ft. above the ground.

alternate hosts may have entered HMF earlier, but the specialists must have arrived with or after the gypsy moth, circa 1970. The present gypsy moth invasion of HMF undoubtedly resulted from the general spread into the state discussed earlier. First-instar larvae were probably blown in from the Sourland Mountains, where heavy defoliation occurred in 1971 and 1972. The Somerville population of 1920 may have spread somewhat into HMF—Weiss (1922) indicated scattered egg masses in the East Millstone vicinity. The sticky-tar bands (to prevent larval ascension of trees) still visible on oaks near the tourist trail are evidence of the early eradication program.

Table 4. Average incidence of parasitism and disease based on pupal and larval counts at 13 sampling stations

|   | 1975  | 1976  |                   |
|---|-------|-------|-------------------|
|   |       | Male  | Female            |
| Larvae <sup>a</sup> (3rd to 6th instar) | 714   | 582   |                   |
| <i>Parasetigena</i> parasitism          | 5.6%  | 25.4% |                   |
| Disease <sup>b</sup>                    | 14.6% | 11.2% |                   |
| Pupae                                   | 422   | 107   | 75                |
| Survival to adult                       | -     | 93.4% | 60.0%             |
| Tachinid parasitism                     | -     | 2.8%  | 25.3%             |
| Other parasitism                        | -     | -     | 1.3% <sup>c</sup> |
| <i>Calosoma</i> <sup>d</sup> predation  | -     | 1.9%  | 6.7%              |
| Disease <sup>b</sup>                    | -     | 1.9%  | 8.0%              |

a. sexes combined

b. nuclear-polyhedrosis virus

c. ichneumonid, probably *Theronia atlantae*, a native species

d. probably *Calosoma scrutator*, a native species

An important aspect of parasitism in terms of population control is the sex-specific rates. Based on the pupal survival rate (Table 4), the adult female to male ratio in 1976 was 0.45. This can be explained almost in its entirety by the greater overall rate of parasitism of female larvae by *Parasetigena*. Larvae can be sexed only in the last instar by the fact that females have one more instar than males. Parasitism of 6th instar larvae (all females) reached 58%, while that of 5th instars (assumed 50%

males) was 26%. This difference is thought to be a result of the females having a longer exposure to parasitism by virtue of having an extra instar (about one week's duration) and greater kairomone release due to the larger body size. *Parasetigena* maggots emerge with about equal frequency from gypsy moth larvae and pupae. The sex differences in larval mortality rate reduced the female-male pupal ratio to 0.70, and the subsequent pupal mortality further reduced the adult ratio to 0.45. This explains, in part, the greater number of flying males caught in 1976 vs. 1975 (Table 3) despite 1976's lower larval counts. Another factor which may make the male counts an unreliable index of population is the effect of trap proximity to local high-density populations aggregates.

No coherent pattern of density distribution shifts within the forest emerged from numerous correlation analyses of the Table 1 population data. Egg mass counts in 1974 showed a significant positive correlation when regressed against 1973 counts. This, though, might be an artifact of the re-counting problem mentioned earlier. Larval counts in 1975 were negatively correlated with 1974 egg mass counts on the burlap tree, i.e., sites with high starting populations at egg hatch had low populations at the end of the generation and vice versa. This suggests greater larval dispersion from initially high density sites, or greater mortality. The trend was not consistent the following year, however. The decrease in the coefficient of variation during the first three years does show that the population was becoming more uniformly distributed in the forest. The lack of correlation of rate of parasitism with egg mass or larval counts indicates that *Parasetigena* searching efficiency was independent of host density.

#### Consequences of Future Defoliation

The gypsy moth population in HMF has apparently stabilized as a result, in part, of an equilibration with parasitism and disease. Other factors have been suggested in the past as tending to retard or prevent a heavy infestation in HMF (Campbell, R.W., USDA Forest Service, pers. comm.). The white oaks in HMF tend to have a tighter than usual bark structure which results in a decreased density of protective "bark flap" resting places for larvae and pupae (Campbell et al., 1975). Also, due to the isolated nature of HMF in an agricultural matrix, there may be a net emigration of wind-blown first-instar larvae because of the lack of compensatory sources of immigration. It is problematical whether these factors or others will prevent the gypsy moth population from reaching pest proportion in HMF in the future. Despite enormous investments of time and money over the past several decades, gypsy moth population dynamics are still not well enough understood to enable reliable predictions. Illustrative of the nature of the problem is the history of population fluctuations in Massachusetts—an area for which there has been the longest time for integration (Figure 4).

There is great potential for damage in HMF from heavy defoliation. Kegg (1973) has reported 84% mortality of white oaks and 45% mortality of red and black

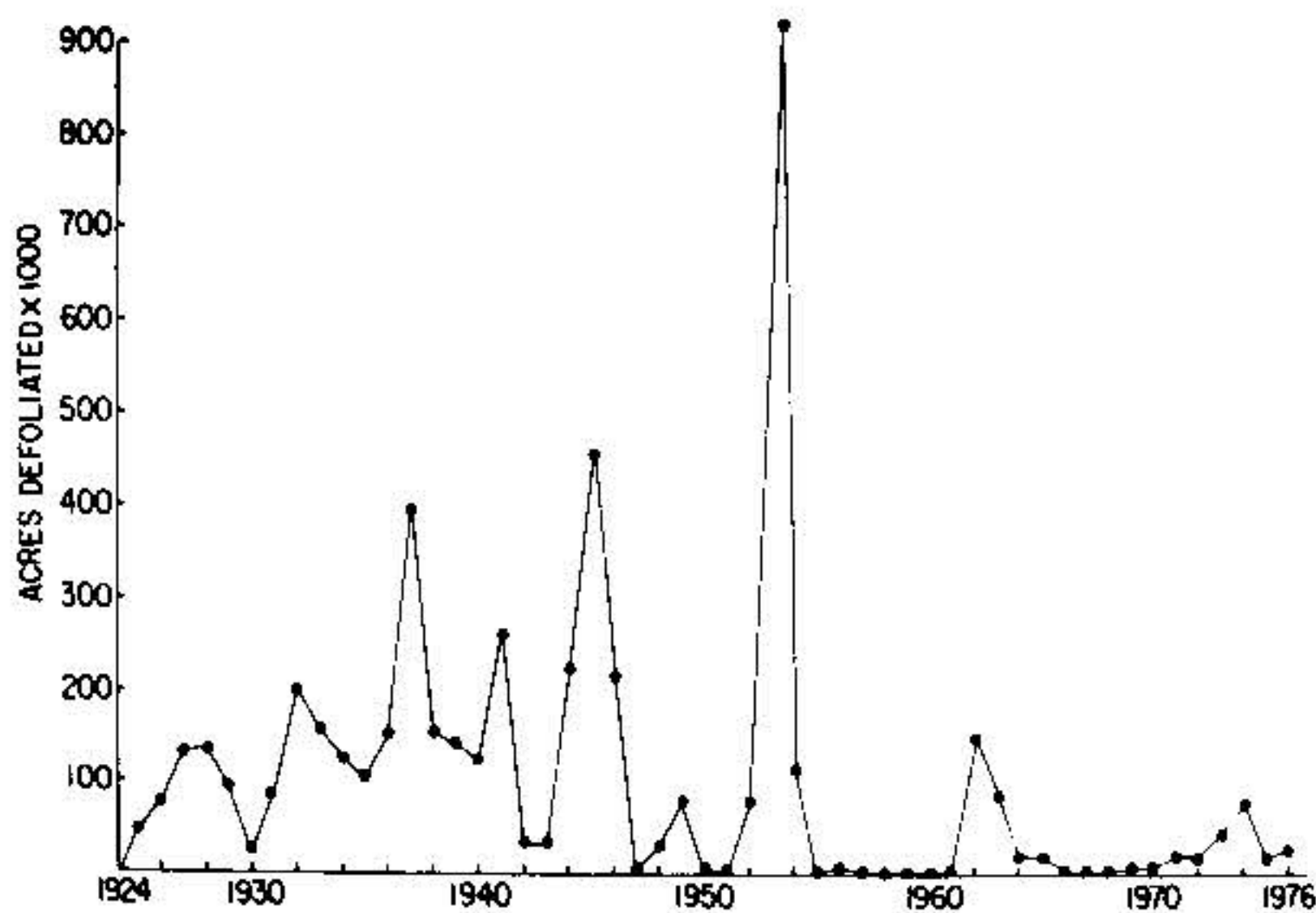


Figure 4. The periodicity of gypsy moth defoliation in Massachusetts. (UDA, Plant Protection and Quarantine, Moorestown, N.J.)

oaks in northern New Jersey after two years of defoliation. Oaks below 12" dbh and above 26" dbh were found to most readily succumb to defoliation (Kegg, 1971). In HMF, oaks of intermediate sizes also appear to be particularly susceptible to defoliation-induced mortality, as seen by their response to other insect pests. Concurrent with the gypsy moth ascendancy in 1974, there was an unusually dense population of fall and spring cankerworms (*Alsophila pometaria* and *Paleacrita vernata*) which reached defoliating proportions at several locations in the forest in late May and early June. Five 18"-24" dbh red and black oaks near the south entrance of the tourist trail were completely stripped during the first week in June, and died during the following winter. Stephens (1971) has observed that the white-oak group (*Lepidobalanus*) is much less able to withstand defoliation than the red-oak types (*Erythrobalanus*). Therefore, since the former is preferred by the gypsy moth and it constitutes approximately half of the canopy tree basal

area at HMF (52% in 1956; Monk, 1961), heavy mortality of this species would undoubtedly occur, and thereby profoundly alter the structure of the forest canopy.

In the event of an extensive gypsy moth outbreak in HMF in the future, I estimate that overall mortality of oaks would approach 75%, or higher if defoliation continued for a second year. Slight mortality would probably occur in hickories especially after two years defoliation. Beech, cherries, and perhaps the maples would be defoliated, but no mortality would be expected since these species are very resistant. The remaining major canopy species, white ash, would be unaffected since it is not fed upon. Similarly unaffected would be the dogwood understory, the viburnum-spicebush shrub-layer, poison ivy, and greenbrier. If food-stress occurred, migrating caterpillars would be expected to move into adjacent old fields and feed upon boxelder, multiflora rose, and perhaps red cedar. Cedars would be killed by one defoliation; the other species would probably suffer no permanent damage. Table 5 summarizes the predicted results of such a situation.

Considering the magnitude of the potential effects of a gypsy moth outbreak, it is recommended that in the future the population be monitored to alert people who may be conducting research in the forest or who might wish to initiate studies of the expected changes. A protocol for this could be established with the Division of Plant Protection, N.J. Dept. of Agriculture.

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Table 5. Predicted effects on canopy trees after extensive defoliation by gypsy moth

|              | % Basal Area        |                    | Trees/A             |                    | % Cover             |                    |
|--------------|---------------------|--------------------|---------------------|--------------------|---------------------|--------------------|
|              | Before <sup>a</sup> | After <sup>b</sup> | Before <sup>a</sup> | After <sup>b</sup> | Before <sup>c</sup> | After <sup>b</sup> |
| White oak    | 52                  | 15                 | 30                  | 3                  | 33                  | 3                  |
| Black oak    | 22                  | 32                 | 13                  | 6                  | 17                  | 9                  |
| Red oak      | 12                  | 18                 | 13                  | 6                  | 26                  | 13                 |
| Hickory spp  | 6                   | 13                 | 8                   | 7                  | 9                   | 8                  |
| White ash    | 3                   | 9                  | 22                  | 22                 | -                   | -                  |
| Red maple    | 3                   | 9                  | 18                  | 18                 | 10                  | 11                 |
| Sweet cherry | 2                   | 3                  | 8                   | 8                  | -                   | -                  |
| Sugar maple  | < 1                 | < 1                | 2                   | 2                  | 4                   | 4                  |
| Am. beech    | < 1                 | < 1                | 2                   | 2                  | -                   | -                  |
| Norway maple | < 1                 | < 1                | 2                   | 2                  | -                   | -                  |
| Open space   |                     |                    |                     |                    | 1                   | 52                 |

a. Based on data from Monk, 1961.

b. Author's estimate.

c. Based on data from Sulser, 1971.

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