Aerial Application of Insecticides for Control of the Gypsy Moth

With studies of effects on non-target insects and birds

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ABSTRACT

Three new insecticide formulations were applied at 1 pound per acre in a total volume of 1 quart per acre. The formulations were Dylox® 80% A.S.P., a powder used with summer oil, 2,3 dimethyl(2,2,2-trichloro-1-hydroxyethyl) phosphonate; Gardona® in oil, 2-chloro-1(2,4,5-trichloro-phenyl) vinyl dimethyl phosphate; and Sevin®-4-oil (1-naphthyl N-methylcarbamate).

All formulations gave excellent foliage protection. Based on drop net collections indicating an average prespray larval density of 75×10^4 larvae per acre there was at least 99% kill of gypsy moth larvae in the plots. In plots 1 (Dylox) and plots 2 and 4 (Sevin) the kill was almost complete while in plots 3 (Gardona) and 6 (Dylox) there was some survival.

Reduction in the number of egg masses per acre was excellent in all plots with the exception of plot 6 where survival apparently was due to uneven or light application of Dylox. However, when properly applied all three formulations reduced gypsy moth density to low levels.

Many different species of non-target insects were affected by the insecticides. Leaf feeding lepidopterans seemed equally susceptible to all three formulations. Sarcophagid and tachinid flies were not affected by Sevin but were reduced in numbers by both Dylox and Gardona. Residues of Sevin-4-oil were tenacious and highly toxic to gypsy moth larvae for at least 8 weeks. Those of Dylox and Gardona were not toxic after the first rains. At 20 days after treatment residues of Sevin-4-oil were highly toxic to *Calosoma* beetle adults.

Birds were not directly affected by the insecticides but the treatments depleted available food and altered bird activity.

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INTRODUCTION

The gypsy moth, *Porthetria dispar,* continues to be a serious defoliator in woodlands in Connecticut. Certain woodlands need protection from heavy defoliation by the gypsy moth, especially those with high timber, scenic, or recreational value. Trees such as large specimen oaks, primarily white oaks, white pine, hemlock, and spruce are particularly susceptible to injury by defoliation. Application of insecticide by air is the only method available at the present time for rapidly controlling dense populations of the gypsy moth.

Although the formulations under test are new, the insecticidal constituents they contain have been tested against the gypsy moth for several or more years. Carbaryl (Sevin) was found to be highly toxic to the gypsy moth in 1959 (Connola and Sweet 1961; Keller *et al.* 1962) and has been used extensively for gypsy moth control since that time. The organophosphate insecticides, Gardona (SD8447) and trichlorfon (Dylox) were first found effective against the gypsy moth in ground spray tests (Doane 1966). Aerial spray tests confirmed that both trichlorfon and Gardona were effective against the gypsy moth at the rate of 1 pound per acre (Anon 1967). They reported an average percent reduction in egg masses per acre ranging from 84% to 99% for Gardona and from 84% to 98% for trichlorfon. In tests the following year trichlorfon gave good foliage protection (Merriam *et al.* 1967, Merriam 1967) and the reduction in the number of egg masses per acre in the prespray to the postspray generation was 2000 down to 2. Aerial applications of all three materials at less than 1 pound per acre generally gave unsatisfactory control.

Currently, only one material, the formulation of carbaryl known as Sevin-4-Flowable is used for air application. This study was initiated with the conviction that more versatility and choice are needed than that offered by a single compound or formulation. The three formulations tested are new and are designed for use from the air.

An area with a very dense population of the gypsy moth was selected for the test since it is under such conditions that most airplane application will be made.

Observations were made on the effects of the treatments to non-target insects and birds.

METHODS AND MATERIALS

Fifty-acre plots were established in the town of North Stonington where there was a dense population. Much of the area had heavy defoliation the previous year. Criteria for establishment of a plot in a particular location included the following: woodland composed predominantly of oak species, large numbers of gypsy moth egg masses per acre that were medium (250 to 500 eggs per mass) to large (500+ eggs per mass) in size, and adequate woodland area around each plot suitable for the untreated control. A suitable woodland control area outside each plot was considered essential since distribution of populations may vary greatly within short distances. For example, Doane and Hitchcock (1963) found that although the original distribution in density of egg masses between plots was uniform there was a marked change in density between the plots after hatch. These changes resulted in larval densities in the control plots that were much different from those selected for treatment.

Three new formulations of insecticides were tested: (1) Dylox® 80% A.S.P., an air-milled powder which was mixed with summer oil at the time of application. Dylox, commonly known as trichlorfon, is 2,3 dimethyl (2,2,2-trichloro-1-hydroxyethyl) phosphonate; (2) Gardona® in oil, a 4 lbs/gal formulation, is 2-chloro-1-(2,4,5-trichloro-phenyl) vinyl dimethyl phosphate; (3) Sevin®-4-oil, a new carbaryl formulation, is 1-naphthyl N-methylcarbamate. The Gardona and Sevin formulations were ready mixed while the final formulation of Dylox was completed in a mixing tank at the airfield prior to application. Certain ULV (ultra low volume) formulations of Dylox were injurious to acrylic paints on cars, but the present formulation was tested and found safe (Merriam 1970).

All sprays were applied with the USDA Pawnee Piper aircraft on May 28. Sevin and Gardona were applied in the morning and Dylox in the evening. Each spray was applied at approximately 1 pound per acre of insecticide in a total volume of 1 quart of spray per acre. Motorola "Handie-Talkie" radiophones were used for ground to air coordination during spraying. One or two observers were in each plot as the spray was applied. Black poster cards, 5″ × 5″ were placed along the lines of nets with two or three being placed near each drop net. These cards worked well with spray deposits of Sevin or Dylox which were easily visible but not with deposits of Gardona. Oil-sensitive cards should have been used in the Gardona plots.

Sapling trees with opaque white plastic garbage bags pulled over the foliage at the top were used to mark the corners of each plot. A tree climber wired each sapling to the top of a large tree at each corner of the plot so that the sapling was above the canopy and clearly visible. The edges of the plots and sampling trails were marked with colored surveyors' tape. No sampling of any kind was done within 100 feet of the plot edge.

Sampling Procedures

Pre-treatment estimates of the population density were made by counting the number of egg masses in 1/16th acre areas in about six locations in each plot while trees were still dormant. Only those egg masses in sight from the ground were counted; no attempt was made to climb trees or overturn material on the ground in search of egg masses.

After hatch, pre-treatment counts of the number of larvae per twig terminal were made on May 19 to 21. At this time there were about six partially developed leaves per twig terminal so counts were based on units of six leaves. If a terminal had only five leaves, one from a nearby terminal was included in the count. Twig terminals were selected at random as each observer moved through the woods and counts were made both in the plot and in the control area.

The stage of development of the larval population was estimated before spraying by examination of living larvae on leaves near the ground. After the sprays were applied the stage of larval development was obtained from larvae falling into the nets. This gave an estimate of the size of larvae in the upper canopy.

Cloth drop nets 1 yd × 1 yd were placed in two rows across each plot starting about 100 paces in from the edges. Plot 1 had seven rather than six nets. Three or four nets were used in each of the five control areas. The nets were placed in the plots about a week before the treatments were applied to monitor any pre-treatment mortality of larvae. Just before treatment all nets were cleared of debris. After treatment dead insects and frass were collected from the nets at irregular intervals. The nets were cleared after each collection. Collections of frass were oven dried before they were weighed.

Post-treatment counts of the number of living larvae were made on 24-inch branch terminals and on 24-inch sections of oak trunks using ½ the circumference of the trunk about chest height. Trees and branch terminals were selected at random as the observer moved through the woods.

In November, after leaf fall, a final estimate of the number of egg masses per acre was made using the method of counting described earlier. At this time hatched egg masses from the previous generation still adhered to the trees and in protected locations many of these egg masses still retained the dark tan color of new egg masses. This made recognition of new and old egg masses in the upper story of trees difficult and somewhat inaccurate. A second counting method was used to compare the number of egg masses in the plots and in their controls. All egg masses on the first six feet of trunks of randomly selected oaks were counted. Egg masses could then be checked to confirm whether they were new or old.

Residual Toxicity of Spray Deposits

Residual toxicity of the materials was bioassayed by exposing gypsy moth larvae to surfaces of treated leaves. Twigs and small branches were collected at various locations in each plot and brought to the laboratory. Leaves were then removed from the twigs and branches and placed in plastic boxes (4″ × 11½″ × 2½″) so that the bottoms were covered. Leaves from one location formed one replicate. About 10 larvae were placed in each box. Field-collected larvae were used for bioassay up to June 30. After this time larvae reared in the laboratory until the

5th and 6th instar were used. Such larvae fed readily on oak leaves although they had been reared on the artificial diet described by Leonard and Doane (1966).

A few *Calosoma* beetle adults were also exposed to treated and untreated oak leaves using the same technique described below.

Field Observations on Non-target Insects

Various attempts were made to assess the effects of the treatments on insects other than *P. dispar*. We were unable to devise methods of obtaining quantitative field data on Hymenoptera, particularly bees and parasitic wasps. Most species observed were sparsely distributed and it became obvious that rather involved observations would be necessary to obtain even a small amount of data.

There was, however, a complex of sarcophagid and tachinid flies in all of the plots and a method of measuring their abundance was devised. They are easy to see and tend to remain active in one area. Counts of flies sighted in a 10-minute period were made as each observer moved through the woods. After pausing for about one minute at each location the observer moved forward about 10 paces. Counts were made on warm, sunny days between 10 AM and 3 PM. The observers alternated counts between treated and untreated areas to minimize any effects of diurnal activity.

Non-target insects collected in the drop nets were counted and grouped according to order.

Effect on Birds

Pre-treatment bird "activity" counts and follow up post-treatment counts were performed in an attempt to monitor effects of the spray treatments on birds. These bird activity counts were designed to measure bird activity within the 50-acre plots rather than bird species seen within the plots as has been done previously (Doane and Hitchcock 1964).

One control area outside of plot 4 and three treated plots (Nos. 3, 4 and 6) were monitored for any change in bird activity. Two one-hour counts, timed precisely, were made on each of eight days in each of the four plots monitored. On each day of a count, the observer was in the plot prior to sunrise and the first of the two counts commenced at astronomical sunrise. The second count commenced 15 minutes after the first count (75 minutes after astronomical sunrise).

Two parameters recorded were each distinct sighting and each "hearing" of a call or song. The former was recorded on tally sheets and the latter was recorded on magnetic tape using a portable tape recorder. The counts were made while walking at a comfortable pace, stopping at any point to make determinations of sightings and constantly recording all hearings.

As an additional check on bird activity, notes were made on all nests discovered in the test plots, as well as in the three additional spray plots not assessed for bird activity. Some nests were revisited to detect any abnormalities as late as June 10.

RESULTS AND DISCUSSION

Effects on the Gypsy Moth

Pre-treatment Counts

Counts of the numbers of egg masses per acre are given in Table 1. On the basis of these counts and other criteria noted in the Methods, it was estimated that all plots would be at least 70% defoliated if no treatments were applied. The range in the density of egg masses varied considerably but plots 2 and 4 appeared to be most heavily infested.

Pre-treatment counts of larval density were made on May 19-21 when larvae were in the first and second instars (Table 2) and the period of first instar larval dispersion was over. There was little variation in larval density between each plot and its control. It appeared that plots 2 and 4, earlier indicated by egg mass counts, still supported the heaviest populations. While there had been no drastic change in density in any of the plots, it is possible for such change to occur during the first instar. Contributing factors may be dispersal of the first instar larvae due to crowding in dense populations (Leonard 1968, 1971) and outbreak of disease in the first instar (Doane 1970).

In one location in the control area in plot 1, there were about 2.4 larvae per terminal near the ground level compared with 6.4 larvae per terminal in the upper half of a large white oak. This density of one larva per leaf was probably representative for the upper canopy of the plot. The relationships in numbers of larvae in upper to lower leaf canopy was probably close to 1:3 for all plots. Later defoliation estimates confirmed that a density of two larvae per terminal near the ground was adequate to produce more than 70% defoliation.

When sprays were applied most larvae near the ground were in the second to third instar (Table 3). Larvae in the lower part of the canopy were developmentally behind those in the upper canopy since net collections on May 29 indicate that most of the larvae falling from the trees were in the third instar.

TABLE 1. Pre-treatment count of the average number of egg masses per acre in and around spray plots, with the range of egg masses per acre encountered in each area. Counts were made in April 1970, before bud break.

Plot	Insecticides later applied	Number of Egg Masses Per Acre: Average	Range
3	Gardona	2850	1,500–3,260
2	Sevin	7610	4,100–13,000
4	Sevin	5155	1,610–8,130
1	Dylox	1790	860–3,200
6	Dylox	2750	960–3,840

TABLE 2. Pre-treatment counts made on May 19, 20, and 21 of the average number of larvae per twig terminal of six leaves. An average of 33 terminals were counted in the plots and 21 in the control areas.

Plot	Insecticides later applied	Average number of larvae per terminal: Plot	Control
3	Gardona	2.6	2.5
2	Sevin	3.12	3.4
4	Sevin	3.9	3.8
1	Dylox	2.2	2.4*
6	Dylox	2.2	1.9

* 6.4 larvae per terminal in top of large white oak.

Post-treatment Counts

Post-treatment net collections of dead gypsy moth larvae are given in Table 4. Most mortality occurred within the first day. The collections made on the fourth day represent the kill for a two-day period. It was noted that some of the larvae falling into the nets on the fourth day were dry and shrivelled. They had probably been dead since the first day and were dislodged by wind.

Kill of larvae tended to be slower in plot 2 than in plot 4. Surviving larvae were observed in the plot for at least 2 weeks after application. However, due to the persistence of Sevin residues most larvae were eventually killed, some as late as the 5th instar.

Post-treatment counts of living larvae in the plots and controls were made at 12 and 13 days after treatment (Table 5). There were great reductions of living larvae in all plots, particularly in plot 4 where we were unable to find any living larvae after an extended search.

The feeding rate as measured by the amount of frass falling into the

TABLE 3. Percentage of larvae in instars based on a pre-treatment count of living larvae near the ground (May 26) and counts of dead larvae falling into the drop nets at 1, 4, and 7 days following treatment.

Date	Instar I	II	III	IV	No. larvae in sample
Living larvae on leaves					
26 May	5.5	89.3	5.1	0	469
Dead larvae in nets					
29 May	1.9	21.6	76.3	0	720
1 June	0	4.2	91.9	3.8	286
4 June	0	0	78.0	22.0	50

TABLE 4. Average number of dead gypsy moth larvae per net in treated and untreated plots at various intervals after treatment. The nets were cleared at time of collection.

Plot	Treatment	Days After Treatment 1	2	4	7	11
3	Gardona	101	18	29	7	1
	Control	1	0.6	4	1	0
2	Sevin	63	32	57	34	5
	Control	2	3	0	0	1
4	Sevin	55	17	27	....	8
	Control	0	0	1	....	0.6
1	Dylox	78	35	35	9	0.4
	Control	0.3	0	0	0.3	0.6
6	Dylox	72	52	29	7	0.8
	Control	5	0	1	1	0

drop nets was very low in all treatments (Table 6). The slightly higher rate of feeding in plot 1 occurred because 2 nets were in an area at one end of the plot where coverage was light. They were located near a sharp incline that prevented the pilot from flying at the proper height above the canopy. After checking the cards on the day following the spray we moved the nets further into the plot but apparently not quite far enough to get into properly sprayed area.

TABLE 5. Mean number of gypsy moth larvae on branch terminals and on sections of oak trunks on June 10 and 11, 1970.

Plot No.	Insecticide	Larvae per 24" branch terminal: No. terminals counted	Mean no. larvae per terminal[2]	Trunk count[1]: No. counted	Mean no. larvae per 24" section[2]
3	Gardona	89	0.1± .093	85	0.05±.01[3]
	Control	63	9.7±1.30	69	1.40±.33
2	Sevin	79	0.7± .22	65	0.10±.07
	Control	59	5.0± .58	57	2.10±.38
4	Sevin	31	0.0±	34	0.00± ....
	Control	31	4.0± .86	31	1.30±.40
1	Dylox	46	0.5± .26	47	0.08±.08
	Control	33	8.0±2.13	32	1.50±.40
6	Dylox	28	0.3± .23	34	0.03±.01
	Control	24	10.5±1.89	28	1.03±.41

[1] The number of larvae in an area of trunk 24" long by ½ the circumference at about chest height. Trunks selected were in the 6" to 12" range.

[2] All t values for difference between treatment and control were significant at the .999 level.

[3] Confidence intervals at the 95% level.

TABLE 6. The relative amounts of frass falling into drop nets in treated and untreated woodland. The June 9 and 16 collections represent 1-day and 7-day accumulations respectively.

Plot. No.	Insecticide	Mean wt. in grams of frass per net: June 9	June 16
3	Gardona	0.04	0.26
	Control	9.19	67.20
2	Sevin	0.31	1.12
	Control	4.00	25.33
4	Sevin	0.00	0.03
	Control	3.90	21.50
1	Dylox	0.37	2.18
	Control	7.75	49.00
6	Dylox	0.06	0.51
	Control	6.25	53.90

Defoliation Estimates

Pre-treatment defoliation of oaks was less than 10% just before the sprays were applied and damage mainly consisted of small holes in leaves, primarily in the crowns of trees. Defoliation virtually ceased in all plots a day or so following application of the various insecticides. The amount of post-treatment defoliation was estimated on July 9, using index ranks of <10%, 10-30%, 30-50%, 50-70%, 70-90% and >90%. Post-treatment defoliation in all treated plots remained at less than 10%. Defoliation of untreated oaks in the control areas around the plots was in the upper range of the 70-90% rank, with many locations being more than 90% defoliated. One exception was the control area for plot 4 where defoliation ranged from 50-90%. Since this was originally one of the most heavily infested plots, defoliation would have probably exceeded 90% except for outbreak of nuclear polyhedrosis virus disease. Disease among late instar caterpillars was severe in all control areas and greatly reduced larval density. It was particularly notable around plot 4. Counts on June 11 showed that at least 14% of the larvae on the lower leaves had died from infection from nuclear polyhedrosis virus. This indicates a much higher infection rate since cadavers soon disappear from the leaf surfaces. Disease incidence is also higher in the tops of trees (Doane 1970). During the last 10 days in June the climactic wave of the epizootic occurred and defoliation in much of the area stopped.

Egg Mass Density

Post-treatment counts for the number of egg masses inside and outside of each plot showed a reduction in numbers of egg masses in the plots significant at the .999 level for t (Table 7). Few egg masses were found in plot 2 and none were found in plot 4. In plot 3, Gardona, the distribution of egg masses throughout the plot was uneven, with most of the plot being free of egg masses except for an area toward one end.

TABLE 7. The number of egg masses per acre and number of egg masses on the basal six feet of trunk on trees selected at random. Counts were made November 23, 24, 25, and 30, 1970.

				Counts of egg masses on first 6 feet of trunk		
Plot	Insecticide	No. 1/16 acre counts	Estimated no. egg masses/ acre[a]	Trunks counted	% trunks with at least one egg mass	Mean no. of egg mass per 100 trunks
3	Gardona	35	42	305	6.2	8.1
	Control	11	1168	213	38.0	226.0
2	Sevin	15	7	149	0.7	1.3
	Control	15	1264	162	33.9	139.0
4	Sevin	12	0	141	0.0	0.0
	Control	11	2016	103	47.0	235.0
1	Dylox	21	10	263	4.1	9.8
	Control	11	2912	148	45.9	221.0
6	Dylox	26	320	418	8.1	13.0
	Control	13	4176	145	49.6	320.0

[a] The t value for means of egg masses per 1/16 acre were significant at .999 level for all plots and their controls.

Thus it is suspected that spray coverage was uneven in this area. Plot 1, treated with Dylox, had few egg masses per acre. In the second Dylox plot (6) there was considerable survival of larvae as indicated by the number of egg masses per acre. This plot was sprayed in the evening when the spray did not settle well due to warm air currents rising from the woods. Uneven and light coverage of insecticide probably accounted for survival of some larvae in this plot.

The trunk counts of egg masses also reflect the effectiveness of the treatments (Table 7) and more accurately indicate survival since old egg masses could be separated from new. A discrepancy will be noted between the per acre count and the trunk count in plot 6 if one compares these with the counts in other plots. The per acre density of egg masses in plot 6 is probably an overestimate. This was due to a tendency to include old egg masses in the upper branches in a count if new egg masses were encountered near the ground.

The size of egg masses in sprayed and unsprayed woodland was also measured. Single egg masses were collected in 1 oz plastic cups during the egg mass counts and all eggs in each mass were counted including eggs parasitized by *Ooencyrtus kuwanai* (Table 8). There were too few egg masses for counts in the two Sevin plots. Egg masses in the remaining plots were larger than in the control areas although the difference was not statistically significant in one of them.

The same effect was found in an earlier study (Doane 1968). In dense populations starvation and disease result in smaller adults and egg masses. Epizootics of nuclear polyhedrosis are, in large part, density-

TABLE 8. Egg mass size and range in size in treated and untreated plots.

Plot	Insecticide	Number of egg masses counted	Average eggs/mass	Range in number eggs/mass
3	Gardona	19	411.2	239–735
	Control	21	167.9***[1]	28–268
2	Sevin	....	....	....
	Control	21	242.0	42–433
4	Sevin	....	....	....
	Control	21	264.6	53–500
1	Dylox	6	298.5 N.S.	68–556
	Control	18	185.0	46–542
6	Dylox	9	500.2	120–886
	Control	28	224.3***	58–453

[1] Difference significant at the .999 level of t.

dependent (Doane 1970). In sprayed woodland an insecticide may thin a larval population allowing surviving larvae adequate food supply and escape from disease by decreased larva-to-larva contact. Females from such larvae produce large egg masses.

The significance of larger egg masses in terms of early return to high larval density is not yet clear. Observations of the plots studied by Doane (1968) indicated that in subsequent years the density of the gypsy moth population fell to that in the surrounding untreated woodland. This suggests that areas larger than 50 acres should be selected for study of the response of survivors of an insecticide treatment. Then such survivors would not be influenced by the different biological events occurring in an area where the gypsy moth population has undergone a rapid and natural decline.

Residual Toxicity of Spray Deposits to Gypsy Moth Larvae

Following application of the insecticides there were 6 days without rain. Heavy rains occurred at 7, 9, 10, and 11 days following application. On the 11th day residues of Sevin were quite visible. Visible residues of Dylox had disappeared while those of Gardona never were visible on the leaves. Leaves collected from 13 locations in plot 2 on the 14th day gave an average mortality of gypsy moth larvae of 89.9% (Table 9). On the 18th day collections of leaves were made in plot 1 (Dylox), plot 3 (Gardona) and plot 2 (Sevin) and these were bioassayed against field-collected gypsy moth larvae. There was no mortality (5 replicates/51 larvae) of larvae exposed to leaves treated with Gardona. There was 2.5% mortality (8 replicates/81 larvae) of larvae exposed to leaves treated with Dylox. There was 80.5% mortality of larvae exposed to leaves treated with Sevin (Table 9). Following this date further samples were taken only from the two plots treated with Sevin-4-oil. Mor-

TABLE 9. Percent mortality of 5th and 6th instar gypsy moth larvae after 24 hours exposure to leaves collected from plots sprayed with Sevin-4-oil. Dead and moribund larvae were grouped.

Plot No.	Leaves collected at days after treatment													
	14		18		25		32		41		60		114	
	R/N[1]	% Mort.	R/N	% Mort.	R/N	% Mort.	R/N	% Mort.	R/N	% Mort.	R/N	% Mort.	R/N	% Mort.
2	13/129	89.9	7/72	80.5	8/73	61.6	6/77	61.0	6/92	85.8	6/101	77.2	5/78	5.12
4							6/106	92.4	6/100	83.0	6/104	62.5	4/62	11.29
Control	2/20	5.0	6/61	0.0	1/15	6.66	5/60	0.0	6/73	0.0	5/66	0.0	4/60	0.00

[1] R is the number of replicates. N is the number of larvae tested.

tality of late-instar larvae remained high until at least 60 days after treatment (July 27). A test in which larvae were suspended over treated leaves in boxes showed that there was no fumigation effect. A final collection of leaves was made on September 22. By this time the mortality from residues had decreased to 10% or less in both Sevin plots although residues were still visible on the leaves.

EFFECTS ON NON-TARGET SPECIES

Insects

Mortality Observations

Drop net samples of arthropods other than gypsy moth larvae falling into the nets were recorded and grouped according to order (Table 10). Non-target *Lepidoptera* were most numerous and were mostly leaf feeders, including leaf rollers (Tortricidae) and loopers (Geometridae). The numbers collected between treatments seemed about equal. There were, of course, far fewer non-target lepidopterans than gypsy moth larvae. Unlike other infestations in Connecticut in 1970, the defoliating infestation in the eastern part of the state was composed mostly of the gypsy moth.

Diptera falling into the nets were mostly calypterate muscids. A small species of green midge (Chironomidae) was found in large numbers in one net in plot 1 and they were also seen in some of the other nets in this plot. These were not included in the counts. A few Coleoptera were found in the nets, especially Elateridae, Lampyridae, and Mordellidae. Some Hymenoptera, Hemiptera (Homoptera) were also caught in the nets. Arachnids were either Araneida (spiders) or Phalangida (harvestmen).

The numbers of non-target species caught in the nets are relatively

TABLE 10. Average dead non-target insects falling into nets from totals collected during the first 6 days following treatment.

Plot No.	Insecticide	No. of nets	Average per net					
			Lepidoptera other than gypsy moth	Diptera[1]	Coleoptera	Hymenoptera	Hom.-Hem.	Spiders
3	Gardona	6	20.6	2.6	2.8	0.5	0.2	0.2
	Control	2	1.0	0.0	0.0	0.0	0.0	0.0
2	Sevin	6	11.1	0.0	0.8	0.3	0.0	0.0
	Control	3	0.3	0.0	0.0	0.0	0.0	0.0
4	Sevin	6	6.8	0.2	1.0	0.2	0.0	0.0
	Control	2	0.0	0.0	0.0	0.0	0.0	0.0
1	Dylox	7	30.8	1.5	0.4	0.0	0.0	0.1
	Control	2	0.5	0.0	0.0	0.0	0.0	0.0
6	Dylox	6	25.8	1.1	0.3	0.0	0.0	0.3
	Control	3	0.0	0.0	0.0	0.0	0.0	0.0

[1] There were about 100 small midges in 1 net—these were not included. Diptera shown are mostly Calypterate muscids.

low if one considers that the figures represent the total catch per net for the 6-day period following treatment. The figures indicate some of the insects that may be killed by the treatments. The low density of non-target insects would require many more nets per plot before representative samples suitable for comparison could be collected. After the 6th day few insects of any sort fell into the nets, even in the Sevin plots.

Observations were made for living insects other than the large calypterate diptera. Bumble bee (*Bombus*) activity was associated with bloom of the huckleberry, *Gaylussacia* species. Bumble bee activity appeared to be normal around huckleberry in Dylox, Gardona, and Sevin plots at 2 and 6 days after treatment. After the bloom period the bees were not often seen. We were unable to collect evidence that bees were being killed since only one or two dead bumble bees were found in any of the plots. There was much mosquito activity in plot 1 before treatment with Dylox. Activity appeared to be the same on the 2nd and 6th day after treatment. No obvious change in deer fly activity occurred in any of the plots. Swarms of midges were noted in plot 1. As noted elsewhere some of these midges were killed but they remained common.

Sarcophagid-tachinid Activity

Ten-minute counts of sarcophagid-tachinid fly activity at 5 and 6 days after treatment are given in Table 11. Sweep net collections and identification of the flies indicated that most of the flies under observation were either in the Sarcophagidae or Tachinidae. The identification and the frequency of the various species making up the complex will not be reported here. There were significantly fewer flies in the Dylox and Gardona plots than in their control areas but in the Sevin plots there were about the same number. The Sevin residues appeared to be non-toxic to these flies. Further observations (up to June 19) indicated that the number of flies remained high in the Sevin plots. These flies apparently do not move far from the point of emergence.

TABLE 11. The number of sarcophagid-tachinid flies in and outside of plots at 5 and 6 days after application of sprays.

		10 minute counts of sarcophagid-tachinid flies	
Plot No.	Insecticide	Number of counts	Mean number
1	Dylox	8	2.3[1] ±1.54[2]
	Control	9	20.0 ±5.89
3	Gardona	10	3.1 ±2.24
	Control	8	18.2 ±8.78
2	Sevin	9	22.8 N.S.
	Control	5	12.4

[1] Values of t for plots 1 and 3 and their respective controls were significant at the .999 level. There was no significant difference between plot 2 and its control.
[2] Values following the means are confidence limits at 95% level.

Later observations in the Gardona and Dylox plots between the 15th and 19th of June indicated that fly density remained sparse. There were many fewer than in the nearby control areas. This again indicated that there was little movement of the flies into the plots from the control areas. This apparent slow dispersion has significance both in sprayed areas and in areas where the gypsy moth population collapses from disease and starvation. Certain species of this complex of flies may not disperse from an area after the gypsy moth population has collapsed.

Evidence suggests that while the effectiveness of parasites or predators may be drastically reduced following spraying with insecticides they are usually not eliminated, even under the most rigorous conditions. Dowden (1961) studied gypsy moth parasites and predators on Cape Cod after several years of DDT spraying for eradication of the gypsy moth. All parasites present before spraying were recovered. The predator, *Calosoma sycophanta* was not recovered.

Residual Toxicity to *Calosoma* Species

A test with a small number of *Calosoma* adults was run on June 18, 1970 with leaves collected from plot 4 and a nearby control area.

Oak leaves were placed in plastic boxes (4″ × 1½″ × 2½″) and one or two *Calosoma* adults were placed on top of them in each box with several gypsy moth larvae. Five *Calosoma frigidum* and one *Calosoma sycophanta* were used in the control boxes with five *C. frigidum* and one *C. sycophanta* in the boxes with treated leaves. By 24 hours only one *Calosoma* adult (*C. frigidum*) was alive in the treated group. There was no mortality of either *Calosoma* species in the control.

This suggests that *Calosoma* species are susceptible to Sevin residues. We have found (Doane and Schaefer 1971) that adults of *Calosoma sycophanta* fly well and may disperse over long distances. They also commonly fly locally from tree to tree, landing on twigs and foliage. Most flights apparently take place during hot days and at such times *C. sycophanta* would be particularly susceptible to insecticidal residues. Grimble *et al.* (1970) found that Sevin residues in woodlands were toxic to adults of *C. frigidum.*

Birds

Dates on the activity counts and the data obtained are presented in Table 12. It is evident that the number of species seen and the total sightings recorded varied little between the plots. Number of species heard and the total hearing recorded do suggest a difference between the control plot and the treated plots. Numbers of species heard in hour one and total hearings for both hour one and hour two indicate more activity in the control plot. Combining these data into 2-hour totals (hour one plus hour two) magnifies these trends (Table 13).

There were 13 to 15 days (lapse time) between the pre-treatment and post-treatment counts. During this lapse time between the counts a

TABLE 12. Data obtained during hour-one and hour-two pre-treatment and post-treatment bird activity counts for four plots sampled. Date of spray application was 28 May 1970 and dates of activity counts are presented. Percentages rounded to nearest whole number while (+) and (−) indicate increase and decrease respectively.

Date		Check May 23 June 7		Sevin May 22 June 6		Dylox May 20 June 3		Gardona May 21 June 4	
		No.	% Change	No.	% Change	No.	% Change	No.	% Change
HOUR ONE									
No. species seen	Pre-	12	−33	10	−30	15	−33	13	−38
	Post-	8		7		10		8	
Total sightings	Pre-	25	−24	17	−12	28	−46	28	−54
	Post-	19		15		15		13	
No. species heard	Pre-	20	+10	19	− 5	26	−35	24	−13
	Post-	22		18		17		21	
Total hearings	Pre-	871	+36	930	+28	712	+38	798	+23
	Post-	1186		1194		983		811	
HOUR TWO									
No. species seen	Pre-	14	−36	9	−56	13	−38	11	−18
	Post-	9		4		8		9	
Total sightings	Pre-	32	−63	26	−73	31	−45	27	−56
	Post-	12		7		17		12	
No. species heard	Pre-	23	−17	15	−27	24	−38	19	−26
	Post-	19		11		15		14	
Total hearings	Pre-	1005	+40	833[a]	...	758	+ 1	d.l.[b]	...
	Post-	1406		d.l.[b]		765		728	

[a] Calculated figure based on 27 minute count, remaining data lost.
[b] Data lost due to tape recorder malfunction.

TABLE 13. The percent increase (+) or decrease (−) in activity after treatments using combined hour-one and hour-two counts.

	% Change			
	Check	Sevin	Dylox	Gardona
No. species seen	−35	−42	−36	−29
Total no. sightings	−46	−49	−46	−53
No. species heard	− 5	−15	−36	−19
Total no. hearings	+36	d.l.	+19	d.l.[1]

[1] d.l. = data lost.

significant change in the bird activity occurred within the plots. Nesting had progressed markedly and late arrivals into the plots had established territories. Progress in nesting implies altered behavioral changes and these no doubt are reflected in the data. Little apparent difference can be detected from the data involving sightings; however, an analysis of the different species heard (Table 14) shows that the species complex changed between the two counts. This change in the percent in categories reflects a change in the species present within the plots. In the category (+Pre −Post) where species were seen in the pre-spray count but were not detected in the post-spray count, the check plot showed fewest species. This is what would be expected in a forest habitat where normal bird activity was not altered by any factors such as insecticides. Furthermore, in the check plot, a greater percentage of species were found in both the pre-treatment and post-treatment counts. Not only did bird species change, but the activity within the plots represented by hearings (calls and songs) changed (Table 15). Table 15 is a selected list of bird species from the total of 39 species heard while making these counts. It contains the four species which contributed greatest to the hearings recorded in all 8 hour-one counts. These data show the absolute change in hearings between pre-treatment and post-treatment counts. No apparent differences emerge consistently in the total change for these 13 selected species. Red-eyed Vireo activity increased in all plots and apparently this species moved into the plots between the two

TABLE 14. The number of species and the percentages of species heard (+) and not heard (−) during the hour-one counts before and after the treatments.

Category	Dylox Plot		Gardona Plot		Sevin Plot		Av. for 3 treated plots (0 excluded)		Check Plot	
	No.	%	No.	%	No.	%	No.	%	No.	%
+ Pre − Post	12	41	10	32	7	28	29	34	4	15
− Pre + Post	3	10	7	23	6	24	16	19	6	23
+ Pre>+ Post	4	14	5	16	6	24	15	18	8	31
+ Pre<+ Post	10	34	9	29	6	24	25	29	8	31
Total species	29		31		25				26	

TABLE 15. Numerical change in hour-one hearings following spray treatments. Listed species placed among the four highest in at least one count. Species are listed in descending order of number of hearings. Negative values are shown parenthetically.

Bird Species	Dylox	Gardona	Sevin	Check
Red-eyed vireo	428	217	445	212
Brown thrasher	(240)	(279)	12	(24)
Black-capped chickadee	6	(34)	(23)	231
Towhee	39	66	(19)	(60)
Blue jay	6	(62)	(67)	(38)
Wood thrush	(25)	(12)	(68)	(40)
Wood peewee	68	5	47	(13)
Crested flycatcher	(10)	10	(8)	(76)
Baltimore oriole	15	35	18	1
Downey woodpecker	3	(10)	(78)	0
Ovenbird	3	(14)	1	13
Black & white warbler	(46)	(8)	1	2
Robin	(10)	65	(11)	(16)
Total overall change	237	(23)	250	192

counts. Other species of birds show decreases, probably due to changes in behavior as nesting and territory establishment progressed.

It is felt that the aerial applications had an indirect effect upon the birds within the plots. In each treatment plot, very good control of the caterpillars resulted. The caterpillars were in early instars (Table 3) and represented a tremendous food source for many species of birds (Forbush and Fernald 1896). Drop net samples indicate that 156 ± 23.7 ($P = .05$, d.f. $= 29$) *P. dispar* caterpillars/yd^2 were killed by the insecticides applied in this test. On this basis, an average of 75×10^4 *P. dispar* caterpillars per acre were eliminated (killed) from the potential food available in the plots, exclusive of the other lepidopterans and other affected insects (Table 10). This kill of insects represents a tremendous loss of food biomass for birds. The 50-acre sprayed plots did not affect nesting birds because they could and did fly readily to areas outside the relatively small plots to obtain food.

Within the six treated plots, 15 bird nests representing 9 species were located. These nests included: 5 Towhee, 3 Wood Thrush, 1 Phoebe (produced two clutches, the first successful, the second outcome unknown), and one each of the White-breasted Nuthatch, Baltimore Oriole, Robin, Red-eyed Vireo, Catbird, and Black and White Warbler. The nestlings in one Wood Thrush nest were preyed upon, probably by Blue Jays. In no case could any mortality in nesting birds be interpreted as a result of the insecticides applied to this test.

The number of bird species feeding on *P. dispar* has been well documented by Forbush and Fernald (1896, 207-8) who present a list of species known to feed on this pest. Several observations by one author, Schaefer, confirm those listed by Forbush and Fernald while one addition is the Worm-eating Warbler (*Helmitheros vermivorus*).

In conclusion, the application of the insecticides caused a depletion

in the available food which altered bird activity. The overall effect was an increased concentration of bird activity in the areas outside the sprayed plots. With nearly 40 species of birds known to feed on *P. dispar* caterpillars and with bird activity altered by the loss of these insects as available bird food, the effect of systematic insecticide coverage on large townships appears detrimental to some birds, particularly to any nestlings which require considerable amounts of food at a time when the insect biomass has been decimated. This bird-insect control relationship should be studied in depth.

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