AERIAL SPRAYING AGAINST SPRUCE BUDWORM ADULTS IN NEW BRUNSWICK

A Compendium of Reports on the 1972 Test Program

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ABSTRACT AND RECOMMENDATIONS

Laboratory tests and field trials of budworm adult spraying were carried out in New Brunswick in 1972 and showed the following results.

Laboratory Tests:

1. Phosphamidon was more toxic than fenitrothion.
2. Males were about twice as susceptible as females.
3. Adults were also susceptible to sprayed foliage.

Field Trials:

1. Contrary to expectation, an early morning application appeared as effective as a late evening treatment, although adults are less active in the morning.

2. Counts of dead adults in drop cloths showed twice as many males as females were killed by the treatment. However, this conclusion requires further checking.

3. Counts of flying females before and after treatment suggested that 85% of the females were killed.

4. Counts of males in virgin female traps after treatment suggested that 75 to 80% of the males were killed.

5. The pattern of kill differed between males and females;- males died very quickly while many dead females were observed 1 day after treatment.

6. Severe mortality of adult parasites and of predatory arthropods occurred in treated blocks.

7. A density of 35 eggs per 10 ft^2 was found in the treated plots versus 60 in the control. The origin of the eggs in the treated blocks was open to question.

Recommendation:

Because females mate and lay the first egg masses very soon after emergence, and males are more susceptible than females, the control objective should be to kill as many males as possible. This could mean spraying very early in the male emergence period.

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INTRODUCTION

In 1944, DDT was tested as a budworm adulticide in Algonquin Park, Ontario. The dosage ranged from 2.0 to 5.0 lb. in 3.0 to 4.0 gal/acre and a report on the operation states:

"As soon as the spray clouds commenced to descend through the tree canopy, moths came fluttering to the ground and contined for several hours. Some of them endeavoured to crawl up the tree trunks, but eventually succumbed to the effects of DDT. Examinations in the late afternoon failed to reveal any living moths ... The pupae and the eggs were not affected by the sprays. The spray deposit remained slightly tacky and retained its lethalness for several days after application. Moths that emerged afterwards seemed to be affected as they continued to drop into the trays, and the plots remained singularly free of moths." Follow-up experiments were apparently not carried out on this promising method of adult control.

In 1969, a budworm-infested forest of about 20,000 acres on the Tobique watershed in northwestern New Brunswick was sprayed in mid-July to determine if aerial spraying could reduce an adult population (Kettela and Flieger, personal communication 1969). The treatment consisted of two applications of Phosphamidon at a total dosage of 4 oz/acre. The first treatment was applied when 40% of the adults had emerged; the second, 3 days later. The operation was monitored on 47 plots by pupal counts before treatment and egg counts after treatment. There was good circumstantial evidence (71 egg masses in the treated plot versus 240 on the control) that the treatment reduced the reproductive capacity of the adult population particularly in high density plots (Kettela, personal communication 1969). These results prompted the development of a joint research proposal in 1972 between Forest Protection Limited and the Maritimes Forest Research Centre to further test adult spraying for budworm control. The following compendium of reports describes the test program and results.

I. LABORATORY TESTS OF FENITROTHION AND PHOSPHAMIDON

C. A. Miller, J. F. Stewart, and D. E. Elgee

Because little was known about the effect of insecticides on budworm adults, the first step in the 1972 program was to conduct laboratory tests and obtain approximate data on: 1) the relative toxicity of fenitrothion and Phosphamidon to budworm adults; 2) the dosage to be used operationally; 3) adult mortality through direct application of the insecticide; 4) adult mortality through contact with treated foliage; and 5) residual effects on treated foliage.

The tested formulations of Phosphamidon (90% technical) and fenitrothion (95-97% technical) were:

(a) 10% fenitrothion in oil - 10% active fenitrothion by volume in 95% Aerotex 3470 solvent.

(b) 5% fenitrothion in oil - As in (a) except 5% active fenitrothion added by volume.

(c) 10% fenitrothion E.C. - Stock solution of emulsifiable concentrate (E.C.) was prepared as fenitrothion (technical), 77.4%; plus Aerotex 3470, 11.6%, and Atlox emulsifier 3409, 11.0%; 10% active stock solution by volume was added to 90% water by volume.

(d) 1% and 0.5% fenitrothion E.C. - As in (c)

(e) 10%, 5%, 1%, and 0.5% Phosphamidon E.C. - Stock solution of emulsifiable concentrate prepared as in (c).

(f) 10% Phosphamidon in water - 10% active Phosphamidon by volume (technical) added to 90% water by volume.

(g) 5%, 1%, and 0.5% Phosphamidon in water - As in (f).

Formulations were applied with MICRON ULVA (battery powered) atomizer with a 1.0 ml/sec emission of formulation. The budworm adults were from a variety of laboratory stocks that has been reared on artificial diet. Potted balsam fir seedlings about 18 in high were used in the foliage tests.

To determine the direct effect of spray on adults, the moths were released into a 4 x 4 x 8-ft plywood box (a conventional spray tower was not available) and the insecticide applied with the atomizer.

Of 21 tests using 187 adults, three had to be discarded because of aberrant results. In each test, five male and five female adults were released into the box, spray was applied for 7 sec, and the air cleared with an exhaust fan for 30 sec. The moths were then collected and placed in lantern globes for observation until death. The results were analyzed by plotting percentage mortality over time and we used these graphs to tabulate the time required for 50% and 75% mortality.

Formulations of 10% and 5% active fenitrothion or Phosphamidon resulted in 100% mortality in less than 6 hours (Table 1). However, the 1% concentrations differed: fenitrothion was relatively ineffective, while Phosphamidon resulted in a quick initial kill and 75% mortality in 24 hours or less. The 0.5% concentrations were both relatively ineffective. The data suggested that concentrations of less than 5%, but greater than 1% would cause adequate adult mortality.

Table 1. Time required for 50% and 75% mortality after the direct application of fenitrothion and Phosphamidon to budworm adults

Treatment	Time (hours) 50% dead	Time (hours) 75% dead
10% fenitrothion in oil	< 1	3
10% fenitrothion E.C.	4	5
10% Phosphamidon in water	2	2.5
5% fenitrothion in oil	< 1	2.5
5% Phosphamidon in water	3.5	5.5
1% fenitrothion E.C.	14	24[a]
1% Phosphamidon E.C.	5	24[a]
1% Phosphamidon in water	4	14
0.5% fenitrothion E.C.	–[b]	–
0.5% Phosphamidon in water	19	> 24[a]

a. Extrapolated.

b. 20% mortality in 19 hours.

To test adult mortality on treated foliage, potted balsam fir seedlings were treated individually with 5% formulations of Phosphamidon and fenitrothion for 2 sec giving an extremely good coverage in the 80 μ droplet range: this approximated a dosage of 0.25 gal (Imp.) of formulation per acre. The foliage was dried for 15 min. Twigs were then collected from these seedlings, placed in glass lantern globes, and five moths were released into each globe. In all treatments, 50% mortality occurred in 6 hours or less (Table 2). Phosphamidon treatments caused 100% mortality in less than 6 hours, while fenitrothion in oil required more than 10 hours to cause 100% mortality.

Table 2. Adult budworm mortality on treated foliage: adults exposed to foliage 15 min after treatment

	Time (hours)	
Treatment	50% dead	75% dead
5% Phosphamidon E.C.	2.5	3
5% Phosphamidon in water	3	3.5
5% fenitrothion E.C.	4.5	5.5
5% fenitrothion in oil	6	9.5
Oil control	14.5	17.5

The above tests showed that adults are killed when exposed to newly treated foliage. We were also interested in the residual toxicity of Phosphamidon and fenitrothion at 4 oz/acre. Potted seedlings were treated with 10% active concentrations of Phosphamidon and fenitrothion and left outdoors for a total of 8 days. Foliage was clipped from the treated seedlings on the first, second, third, fourth, seventh, and eighth day and on each occasion it was placed in a lantern globe and five moths were released into each globe. About 170 moths were observed in these tests. On the first day, all the adults exposed to Phosphamidon-treated foliage died within 6 hours, while 50 to 75% died on fenitrothion-treated foliage. Almost identical results were obtained on the second day after treatment. On Phosphamidon-treated trees, kill was still rapid on the fourth day. In contrast, it was slow on fenitrothion-treated foliage, particularly that treated with the oil formulation.

As noted above, these tests were set up to provide approximate data. They were conducted over a short period using adults from laboratory stock. Within these constraints, the tests suggested: (1) with water as a diluent, Phosphamidon is more effective than fenitrothion in the treatment of spruce budworm adults; (2) a 5% formulation in water was effective in the laboratory and this is broadly within a treatment of 2 oz active ingredient per acre and a total dosage of 0.25 gal (Imp.)/ acre; (3) Phosphamidon is an effective insecticide for adults whether applied directly, or to the foliage they walk on; and (4) in the absence of rain, Phosphamidon remains active on foliage up to 4 days after treatment.

II. TOXICOLOGICAL STUDIES OF FENITROTHION AND PHOSPHAMIDON ON ADULT BUDWORM UNDER LABORATORY CONDITIONS

D. D. Shaw and M. G. Morgan

The extension of the aerial spray program to include the spraying of adult insects has necessitated an evaluation of the relative toxicities of various insecticides on adult budworm. Preliminary tests have been made in the laboratory of the toxicities of Phosphamidon and fenitrothion using a topical application technique (Hewlett and Lloyd 1959).

The innate variability of budworm in response to environmental stress makes them a difficult test insect and toxicological tests must be performed under rigorous laboratory conditions. All insects were reared on artificial diet in the laboratory and were treated at a known age. Insecticides were dissolved in cyclohexanone and known concentrations were applied through a 0.2 µl microcapillary tube placed between the prothoracic legs. All insects were anaesthetised with CO_2, control batches were dosed with cyclohexanone. Two replicates of 8 to 12 insects per sex per replicate were tested and mortality was assessed after 24 hours.

It should be emphasized that the size and number of replicates were not adequate for the amount of variability in response shown by the budworm and it is hoped to increase these in future experiments. However, the results presented in Table 3 clearly show a difference in response pattern according to sex. (Note that the field data in Section IV also show that more males were killed than females.) This kind of

Table 3. LD50 values for both male and female adult budworm showing the difference in response pattern associated with sex

Insecticide	Sex	LD50 (ml/ml)	Ratio LD50 ♀/♂
Fenitrothion	♂	0.00029	2.0
	♀	.00058	
Phosphamidon	♂	.00022	1.64
	♀	.00036	

response pattern is commonly found in a variety of other insects (Busvine 1971) and appears to be a direct weight/response relationship although there is a possibility of a direct sex difference related to different metabolic rates. Similar tests on fourth, fifth, and sixth instar larvae, pupae, and adults again show a correlation between weight and LD50 (Table 4), although here the drastic physiological changes which occur between larva and adult, via pupa, may be implicated. Clearly, these correlations between weight and toxicity may provide information on the kind of dosage application necessary under different field conditions. A correlation between room temperature and response has also been found, although not assessed quantitatively.

Table 4. LD50 values of various stages of budworm after topical application of fenitrothion

Stage of life history (in ascending weight range	LD50
4th instar larvae	23.80
Adults (combined)	37.90
5th instar larvae	36.75
Pupae	74.16
6th instar larvae	89.63

Preliminary tests, using fenitrothion, Phosphamidon, lannate, and pyrethrins, have also been made in the laboratory. The sexed adults (2 days old) were anaethetised with CO_2 and tested in replicates of 8 to 12 insects with two replicates per dose. Control replicates were dosed with pure cyclohexanone solvent. The insecticide was applied between the front coxae using a 0.2 µl capillary tube. Mortality was assessed after 24 hours. The probit regression lines were corrected for natural mortality.

Phosphamidon was the most effective insecticide at both LD50 and LD95 values (Table 5), which agrees with observations in the field. The slopes of the probit lines in the case of the three synthetic compounds were almost parallel. However, the slope of the pyrethrin line was much steeper giving an LD95 value comparable with the other three even though

Table 5. LD50 and LD95 values (in ml/ml or g/ml of cyclohexanone solvent) calculated after topically treating adult budworm of known age

Insecticide	LD50, ml/ml[a]	LD95, ml/ml	Slope	Relative potence LD50	Relative potence LD95
Phosphamidon[b]	0.00028 (0.00034)	0.00126 (0.00154)	2.54	1.0	1.0
Fenitrothion[c]	0.00043 (0.00057)	0.00171 (0.00226)	2.77	1.54	1.47
Lannate[c]	(0.00063)	(0.00261)	2.67	2.25	1.69
Pyrethrins I & II[e]	0.00102	0.00260	4.07	3.64	1.69

a. Values in parentheses are in g/ml.

b. 92% a.i.

c. 95% a.i.

d. 90% a.i.

e. 20% a.i. (Pyrocide 175).

its LD50 was 3.5 times less than that for Phosphamidon. This may prove to be of considerable importance in the assessment of the pyrethrin group as potential field compounds. The efficacy of pyrethroids can be greatly improved by mixing them with synergists like sesame oil and piperonyl butoxide. For instance, a 1:10 mixture of pyrethrins and piperonyl butoxide reduced the LD50 of pyrethrins alone by a factor of 4.6 when applied to Sitophilus granaria (Parkin and Lloyd 1960). In the present case, if the addition of piperonyl butoxide reduced the LD50 value to that obtained for phosphamidon and if the slope remained the same then the LD95 value of pyrethrins would be 1.7 times more effective than phosphamidon - an improvement which would warrant testing in the spray program.

III. DESCRIPTION OF FIELD PLOTS AND SPRAY APPLICATION

E. G. Kettela

Two experimental blocks for adulticide sprays and one control plot were selected near the Dunphy Airstrip at Upper Blackville, Northumberland County, N.B. Each block was about 8,000 acres.

The spray blocks received two applications, each consisting of 2 oz of poison in 0.15 gal (U.S.) of formulation per acre. The fenitrothion was dissolved in Aerotex and emulsified in water; the Phosphamidon was dissolved in water.

Spraying started on 11 July (P.M.). The east and middle thirds of the fenitrothion block received the first application in the evening of 11 July, and the western third on the next morning. The whole block received the second application on the evening of 14 July.

The Phosphamidon block was treated on the morning of 12 July. The second spray was applied to the northern quarter on the evening of 14 July and to the southern two-thirds on the evening of 16 July; the remaining narrow strip was not given a second application. Stearman aircraft equipped with Micronaire nozzles applied the insecticides in weather that was hot and humid.

A total of 10 sampling plots was selected in each of the two treated blocks and the control block to assess the mortality of moths and other arthropod fauna. In each plot, five drop cloths were set up to catch the bodies of dying or dead insects. Each drop cloth was a 2- x 2-foot square of unbleached cotton supported by pegs at the corners; two cloths were placed under the crowns of fir trees, two under red spruce trees, and one in the open among ground vegetation such as raspberry and fireweed. The organisms falling onto the drop cloths were collected daily from 12 to 20 July, with block, plot, and host tree identifications, and stored in 70% alcohol.

Pre-spray Biological Data

(1) Adult emergence data are shown in Table 6. On 11 July, the first spray date, about 90% of the male adults, and 80% of the females had emerged. By 16 July, emergence was complete.

(2) Pupal sex ratios on the three study blocks ranged from 44 to 48% females. This slight bias toward males made little difference when assessing the possible differential mortality of the sexes.

Table 6. Budworm phenology (% of moth emergence) in the control and Phosphamidon spray block[a], July 1972

Date	Control block		Phosphamidon block	
	Males	Females	Males	Females
7	0	7	33	8
8	47	16	52	19
9	64	32	68	35
10	81	52	80	67
11	90	80	93	81
12	92	86	100	86
13	97	93	100	90
14	100	96	100	94
15	100	100	100	95
16	100	100	100	100

a. Data from Greenbank (Section VI).

(3) On 30 June, pre-treatment population counts were taken on the 10 plots in each of three study blocks (Table 7). Two fir and two spruce were sampled in each of the 10 plots per block. One branch was sampled per tree.

Table 7. Mean and range in population density per 10 ft^2, 30 June

Species	Blocks		
	Fenitrothion	Phosphamidon	Control
Fir	47.7 (0-140)	59.2 (10-274)	36.5 (8-81)
Spruce	6.45 (0-48)	14.3 (0-42)	3.40 (0-24)

A seasonal trend plot near Dunphy airport showed a 58% survival from 30 June to the spray date of 14 July and this figure was used to arrive at a population density on the spray date. For example, it was estimated that the pupal case (adult) densities on the Phosphamidon and control blocks at the time of treatment were:

	Phosphamidon	Control
Fir	59.2 x 0.58 = 34.3 adults	36.5 x 0.58 = 21.2 adults
Spruce	14.3 x 0.58 = 8.29 adults	3.40 x 0.58 = 1.97 adults

The only corroborating data were collected by Greenbank (Table 8). He counted female cases on one plot in the Phosphamidon block and on one plot in the control block on 16 July.

Table 8. Comparative female counts (per 10 ft^2) from Greenbank and Kettela, 16 July

	Female count per 10 ft^2	
Block	Greenbank	Kettela's extrapolation
Phosphamidon	11.7	17.2
Control	5.7	4.2

Attempts to convert budworms per 10 ft^2 of foliage to absolute populations per acre produced very rough estimates. Prism tallies were taken at five points in each study block and converted to the number of fir and spruce stems per acre (Table 9). Then, assuming a mean of 500 ft^2 of foliage per stem, the square feet of foliage per acre and budworm adults per acre were calculated (Table 9). The final counts of adults per acre were: Control, 266,380; Phosphamidon, 619,907; and Fenitrothion 411,406.

Table 9. Conversion of pupal counts per 110 ft^2 to adult counts per acre on the three study blocks

Block	Stems per acre	Foliage,[a] ft^2/acre	Pupal density[b] per 10 ft^2	Survival to 14 July	Adults per acre
Control					
Fir	247	123,500	36.5	0.58	261,450
Spruce	50	25,000	3.40	.58	4,930
Phosphamidon					
Fir	342	171,000	59.2	.58	587,146
Spruce	79	39,500	14.3	.58	32,761
Fenitrothion					
Fir	292	146,000	47.7	.58	411,406
Spruce	40	20,000	6.45	.58	7,482

a. Assuming a mean of 500 ft^2 of foliage per tree.

b. On 30 June.

IV. ADULT MORTALITY BASED ON DROP CLOTH COUNTS

E. G. Kettela

The total number of dead budworm adults collected in drop cloths in the two spray and the control blocks is shown in Table 10. The counts are separated by sex, collection date, and whether the drop cloths were under fir, spruce, or in the open. Each count listed in the table represents the number of males or females taken from 20 trays (10 plots x 2 trays per location). To convert this figure to individuals per ft^2, the total number was divided by 80 (20 trays x 4 sq ft per tray). For example, 1508 dead males were counted under fir trees in the Phosphamidon block for the 9-day collecting period. This means that 1508/80 or 18.9 dead males were collected per ft^2 on the ground under fir trees, and this figure, the number of individuals per ft^2, is used in the following discussion. (Note that only one drop cloth was placed in the 'open'. In other words, there were 10 rather than 20 'open' drop cloths per plot.)

Results and Conclusions

(a) Twice as many males as females were killed in both the Phosphamidon and fenitrothion blocks (Table 11). Even correcting the values in Table 11 for the number of dead males and females found in the control plot would not alter the above conclusion, although it is very interesting to note that about five times more males than females were found in the drop cloths in the control block (276/48, Table 10).

Table 11. Comparison of male and female kills on the Phosphamidon and fenitrothion blocks

Trap location	Dead adults per 10 ft^2		Ratio
	Males	Females	♂/♀
		Phosphamidon	
Fir	18.9	9.4	2.0
Spruce	14.5	7.5	2.0
Open	10.2	4.0	2.6
		Fenitrothion	
Fir	4.8	2.4	2.0
Spruce	4.7	2.0	2.0
Open	4.4	1.0	4.4

Table 10. Numbers of dead males and females on the drop cloths in the Phosphamidon, fenitrothion,[a] and control plots

Stand type	July 12	13	14	15	16	17	18	19	20	Total	Number per ft²
					Phosphamidon						
Males											
Fir	579	161	307	239	-	-	214	-	8	1508	18.9
Spruce	457	110	227	175	-	-	184	-	5	1158	14.5
Open	190	51	60	40	-	-	66	-	2	409	10.2
TOTAL	1226	322	594	454	-	-	464	-	15	3075	-
Females											
Fir	60	100	128	198	-	-	255	-	8	749	9.4
Spruce	58	76	101	130	-	-	218	-	13	596	7.5
Open	22	15	23	17	-	-	80	-	1	158	4.0
TOTAL	140	191	252	345	-	-	553	-	22	1503	-
					Fenitrothion						
Males											
Fir	103	61	25	142	39	7	-	4	-	381	4.8
Spruce	93	46	31	145	52	9	-	3	-	379	4.7
Open	32	54	17	51	15	4	-	1	-	174	4.4
TOTAL	228	161	73	338	106	20	-	8	-	934	-
Females											
Fir	22	29	14	82	26	9	-	7	-	189	2.4
Spruce	15	22	19	53	29	11	-	8	-	157	2.0
Open	4	7	5	13	12	1	-	0	-	42	1.0
TOTAL	41	58	38	148	67	21	-	15	-	388	-
					Control[b]						
Males											
Fir	-	30	20	27	-	-	41	-	5	123	1.5
Spruce	-	21	26	32	-	-	41	-	10	130	1.6
Open	-	6	2	0	-	-	12	-	3	23	.6
TOTAL	-	57	48	59	-	-	94	-	18	276	-
Females											
Fir	-	5	3	1	-	-	11	-	3	23	0.3
Spruce	-	3	2	1	-	-	8	-	4	18	.3
Open	-	1	1	0	-	-	4	-	1	7	.2
TOTAL	-	9	6	2	-	-	23	-	8	48	-

a. Counts on only 5 plots on 13 July on Phosphamidon plot.

b. Counts on only 5 plots on 20 July on control plot.

The reasons for the higher kill among male adults are not clear. Toxicological tests by Shaw and Morgan (Section II) showed that males were twice as susceptible as females to the topical application of an insecticide. Or it is possible that the more active males dropped to the ground while the dead females remained on the foliage, giving a biased drop-cloth sample. Differential mortality of the sexes must be checked in further tests.

(b) Phosphamidon was more effective than fenitrothion (Table 12) and even correcting for the pre-spray difference in population (74/54 = 1.4) on the two treatment blocks would not alter the above conclusion. Furthermore, the laboratory tests also showed that Phosphamidon was more toxic.

Table 12. Comparison of kill by Phosphamidon and fenitrothion for males and females in three stand types

		Dead adults per ft^2		
Stand	Sex	Phosphamidon	Fenitrothion	Ratio P/F
Fir	Males	18.9	4.8	4.0
	Females	9.4	2.4	4.0
Spruce	Males	14.5	4.7	3.0
	Females	7.5	2.0	4.0
Open	Males	10.2	4.4	2.0
	Females	4.0	1.1	4.0

(c) The pattern of kill was quite different for the two sexes. For example, of all the males that were found on drop cloths in the Phosphamidon block, 35% died within hours after the first spray, and the second spray on 14 July did not cause a second peak in mortality on 15 July (Table 13).

The pattern of female kill was different. Only 7% of the females died within hours after the first treatment, but 24% died the next day (Table 13). A high rate of mortality also occurred 1 day after the second treatment. The reasons for the differing patterns of kill among males and females are not easily discernible.

Table 13. The pattern of kill[a] among males and females on the Phosphamidon block

	July				
Sex	12[b]	13	14	15[b]	16-18[b]
Males	35	19	18	14	13
Females	7	24	15	24	30

a. Percentages on each date based on the total number of individuals found in drop cloths under fir trees.

b. Immediately after treatment.

The ultimate question - What proportion of the adult population was killed by the treatments? - is almost impossible to answer because of the difficulty of converting pre-spray pupal counts per 10 ft^2 of foliage to adult population per acre and the difficulty of converting counts of dead adults in small rectangular drop cloths to per acre values. However, there is little doubt that the collection of 3,075 dead males and 1,503 dead females in 50 small drop cloths in the Phosphamidon block clearly indicate a high rate of adult kill. Tentative estimates are given in Sections V and VI.

V. MALE ADULT MORTALITY ASSESSED WITH VIRGIN FEMALE TRAPS

E. G. Kettela

In each of the 10 plots within a treatment block, three sticky traps baited with virgin females were established to assess the number of adult males before and after treatment. In all, 2,079 male moths were trapped from 9 to 16 July.

Pre-treatment counts on the three blocks on 10, 11, and 12 July were quite variable (Table 14). For example, it was expected that the Phosphamidon block would show the highest adult density because of the highest pupal density (Table 7) but this was not the case. Thus the following sampling results must be interpreted with caution.

Table 14. Mean number of male adults taken in virgin female traps in study blocks

Date	Control	Phosphamidon	Fenitrothion
9 July			6.11
10	3.97	3.50	.85
11	3.43	2.03	2.22
12[a]	3.23	5.10	5.37
13	6.20	2.67	1.70
14	6.27	1.37	1.41
15	7.53	.60	1.52
16	4.50	1.37	.26
Post-spray[b] mean	6.13	1.50	1.22

a. Spray date.

b. Mean for 13-16 July.

Immediately after treatment on 12 July there was a sharp reduction in the number of males per trap (Table 14). In the Phosphamidon block, the number of males dropped from 5.10 to 2.67 (48% drop) and from 5.37 to 1.70 (67%) in the fenitrothion block. This is all the more impressive because the number of males doubled (3.23 to 6.20) in the control block. A rough estimate of male mortality based on the mean number of males trapped in the control block from 13 to 16 July inclusive is:

$$\frac{\text{Mean males trapped in Phosphamidon block}}{\text{Mean males in Control}} = \frac{1.50}{6.13} \text{ or } 76\% \text{ dead}$$

$$\frac{\text{Mean males trapped in fenitrothion block}}{\text{Mean males in control}} = \frac{1.22}{6.13} \text{ or } 80\% \text{ dead}$$

Such estimates of male adult mortality are very crude but do suggest a degree of mortality exceeding 70%. Tentative conclusions from the counts of males in virgin-female traps are:

(1) Although the drop cloths in the spray blocks indicated extreme male mortality, the virgin female traps showed that a few males did survive.

(2) Counts of dead males in drop cloths indicated a higher rate of kill in the Phosphamidon block than in the fenitrothion block. This conclusion is accepted even though it is not confirmed by the counts of living males (1.50 to 1.22) in Table 14.

VI. ADULT MORTALITY DETERMINED BY OBSERVATIONS OF FLIGHT ACTIVITY

D. O. Greenbank

One method of assessing the effect of a spray program against a spruce budworm moth population is through comparative measurements of local flight activity before and after spray application within sprayed and unsprayed areas. Recent studies on the behavior of spruce budworm moths have provided techniques for measuring flight activity (Greenbank, 1973). Male and female flight patterns become identifiably different when moth activity is viewed from platforms erected about 10 feet above the crown canopy. In brief, male moths typically buzz around the crown periphery usually within a few inches of the branch tips. They are active day and night except for two or three hours around sunrise. Peak male moth activity is at sunset. Female moths generally remain sedentary on the foliage until evening and then activity begins with an abrupt take-off from the tree, a steep climb to heights up to 60 feet above the canopy, and terminates with wind-directed dispersal out of the stand. While the flight pattern of female budworm is adapted to expose the population to wind-directed dispersal, the flight pattern of male budworm is adapted to a 'search and mate' mode within the local population.

Methods

As part of the monitoring of the 1972 adult spray program a 50 ft observation platform was erected within the 8,000 acre Phosphamidon spray block and another within the control block, 5.2 air miles distant. The platforms were manned from 7 to 16 July. Moth activity was measured once every 15 minutes from 1500 to 2130 hours. At each check, 10 instantaneous counts were made of the number of males buzzing around the top six feet of a selected fir crown. Mean counts for each 15 minute check were totalled to provide a daily index of male moth activity (Fig. 1).

Female moth activity was measured for 2 of every 15 minutes by counting the number of females taking-off from a cluster of 10 fir trees, climbing steeply, and emigrating out of the stand. Exodus flights were totalled daily (Fig. 2).

Moth populations were significantly higher in the spray block than the control block. After adult emergence was complete, four branches were collected from 10 fir trees and examined for female pupal cases (emerging females). The population of resident females in the spray block was 11.7 per 10 ft^2 of foliage and 5.7 in the control block. Kettela's pupal sampling in these blocks on 30 June showed a similar two-fold difference in density.

Budworm development was determined daily at 1500 hours (see Table 6). Phenologies were similar in the two blocks, male moth emergence perhaps being completed 1 or 2 days earlier in the spray block. The first spray application was at 0745 hours on 12 July when, in the spray block, over 93% of the males and over 81% of the females had emerged. The second spray application was at 2030 hours on 14 July when male moth emergence was complete and over 94% of the females had emerged.

Results

Male flight activity is minimal in the early morning and on 12 July, prior to the first spray application at 0745 hours, only one or two males were seen buzzing around each tree crown. Fifteen minutes after the spray planes passed over the platform, buzzing activity increased noticeably and at 0830 hours male flight behaviour changed completely. Many attempted to climb vertically only to spin uncontrollably to the ground. Also tree to tree flights became unusually frequent. From 1000 to 1100 hours, the number of males in flight decreased, while the number fluttering on the ground increased. Seven hours after the first Phosphamidon spray application and thereafter, no male moths were seen in flight in the spray block. In contrast, male moth activity continued in the control block with relatively high counts of buzzing males being made on 12 July and 14 July (Fig. 1). This corroborates Kettela's observation based on dead males in drop cloths;- the first Phosphamidon spray caused an immediate and acute kill of adult males, possibly to the extent that the second spray was not required.

Female moths showed no immediate reaction to the spray. On the morning of 12 July, they remained sedentary on the foliage throughout the spray operation and, during that afternoon and evening, the flight behavior appeared normal when a total of 24 females were observed in exodus flight (Fig. 2). Although this was fewer than the previous evening (70) it did represent a sizable population that apparently survived the spray treatment. The real effect of the first spray application on the female population did not show until one day later. On 13 July, only one exodus flight was recorded in the spray block compared to 10 in the control block and on 14 July, three exodus flights as compared to 54 in the control block (Table 15).

The ratio of the number of exodus flights from the control versus spray block can be used to roughly assess mortality of female moths due to Phosphamidon spray. Before spray application, that is on 10 July and 11 July, the ratio was 0.6 (Table 15), which is reasonable knowing that the female moth population on the control block was about half the population on the spray block. After spray application, that is on 12, 13, and 14 July, a ratio of close to 0.6 would also be expected if the spray had had no effect. Thus the expected number of exodus flights from the spray block can be calculated and compared with the actual number of exodus flights.

July 12 - Expected number of exodus flights from spray block $= \frac{26}{0.6} = 43$

July 12 Actual number of exodus flights from spray block = 24

July 13 - Expected number of exodus flights from spray block $= \frac{10}{0.6} = 16.7$

July 13 Actual number of exodus flights from spray block = 1

July 14 - Expected number of exodus flights from spray block $= \frac{54}{0.6} = 90$

July 14 Actual number of exodus flights from spray block = 3

The percent mortality of female moths due to spray was calculated using the equation:

$$\% \text{ mortality} = \frac{(\text{EXP.} - \text{ACT.})100}{\text{EXP}}$$

which provided estimates of 44, 94, and 97% mortality 12, 36, and 60 hours after spray.

On July 15 and July 16, exodus flights were equally numerous from the spray and control blocks and the question immediately arises "was the spray block invaded by moths from surrounding unsprayed areas?"

Neither thunderstorms nor heavy showers were reported in the region during the 5 days, 12 to 16 July, following the first spray application. In the absence of convective storms, the flight behavior of male moths tends to localize male populations. Thus, once the male population had been eliminated in the spray block, zero counts of buzzing males were to be expected even though extensive sources of male moths were only one mile upwind.

In contrast, the flight behavior of female moths under both convective- and non-convective weather conditions is clearly adapted to wind-directed displacement of populations and invasion by females into both the control and spray blocks should be expected. However, the day to day changes in the number of exodus flights from the control versus the spray block do not show evidence of moth invasion (Table 15). The low pre-spray ratios of 0.6 for 10 and 11 July are due to population being lower on the control than the spray block. The high post-spray ratios of 10 and 18 for 13 and 14 July show the effect of the spray on the female moths. However, on 15 and 16 July the ratio of exodus flights from control versus spray block was roughly 1. If invasion of the spray block was responsible for this change in the exodus ratio, one must wonder why invasion into the control block was not equally intensive. On the other hand, if those females which were in the pupal stage at the time of the second spray application, six per cent of the population (Table 6), survived then the number of exodus flights could increase from the more heavily infested spray block while decreasing from the control block.

Further evidence of the effect of the Phosphamidon spray on moth populations is provided by egg counts. The egg population in the spray block was about half the egg population in the control block. The significance of this ratio cannot be over emphasized when it is known that:

a) The female moth population in the spray block was twice the moth population in the control block.

b) That prior to spraying, over 81% of the female population had already reached the adult stage and a large proportion of the potential egg population had already been laid by the resident female population.

Results from this small pilot experiment to test the efficacy of Phosphamidon spray against a spruce budworm adult population must be considered extremely encouraging. The control of spruce budworm epidemics through adult spraying would seem an attractive possibility. Future adult spray programs in New Brunswick should be designed to first reduce populations within a 30-40 mile strip along the western periphery of the New Brunswick infestation. Because of New Brunswick wind patterns in mid-summer, invasion of this strip by populations to the east would be insignificant. Each year the strip to be sprayed should be further to the east.

The target of an adult spray program is the female moth before she lays her first eggs and disperses out of the stand. At any locality, female moth emergence continues over about a 10-day period but some 70% of the female population usually emerges in 4 days. To enlarge the target size on any date, the first spray application should be timed to coincide with peak male moth emergence. Male moth emergence usually begins 2 or 3 days earlier than female moth emergence and the removal of the early appearing males should result in females retaining virginity for a protracted period. Virgin females do not disperse. The second spray application should be 3 or 4 days later.

Table 15. Number of females emigrating from the Control and Spray Blocks

Date	Number of take-offs		Ratio control/spray
	Control block	Spray block	
July 7	2	6	0.3
July 8	4	19	0.2
July 9	45	45	1.0
July 10	51	85	0.6
July 11	39	70	0.6
July 12	26	24	1.1[a]
July 13	10	1	10
July 14	54	3	18[b]
July 15	8	7	1.1
July 16	5	6	0.9

a. First spray application 0745 hours

b. Second spray application 2030 hours.

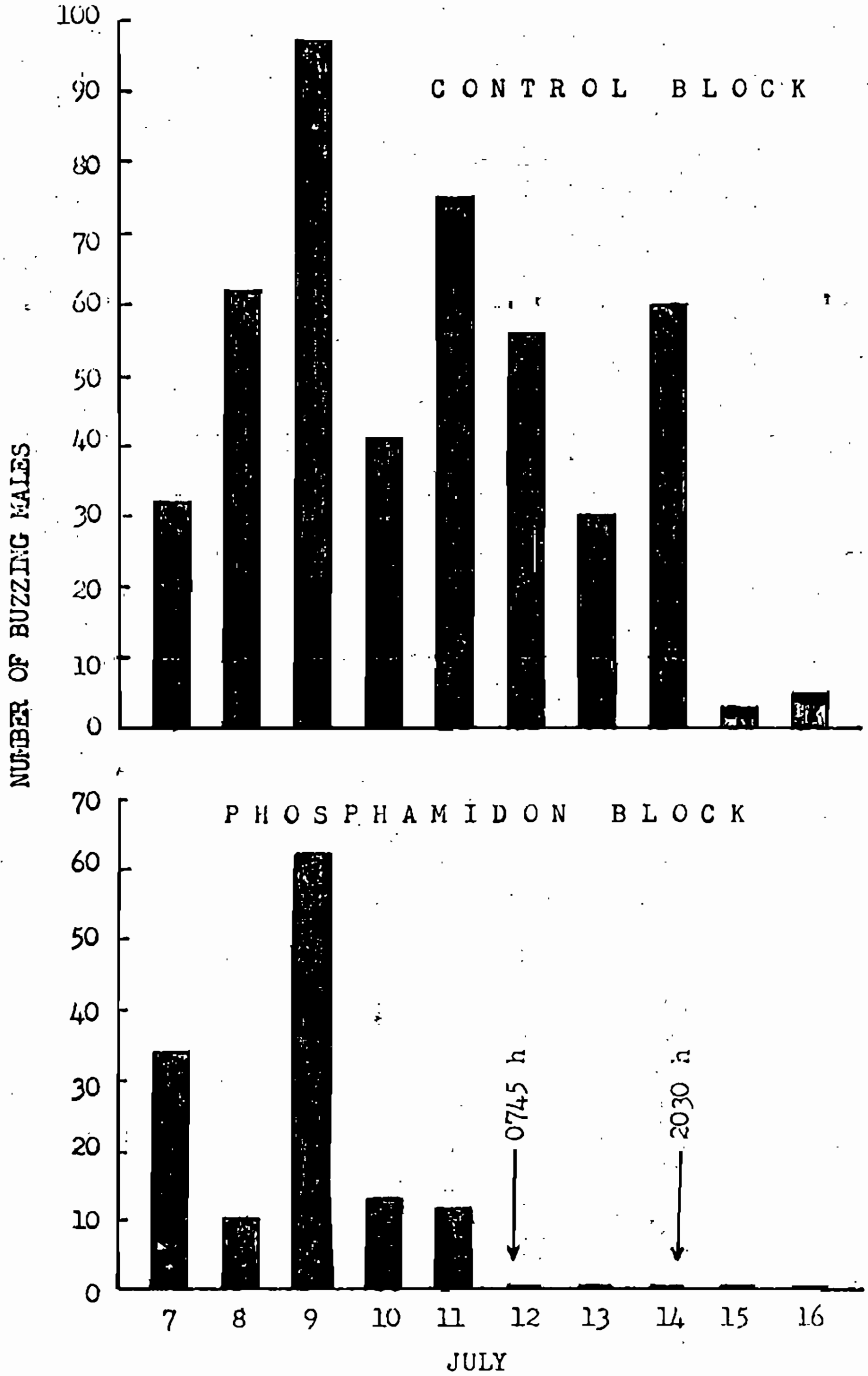

Fig. 1. Male activity on the control and spray blocks over a 10-day period that includes the two spray dates.

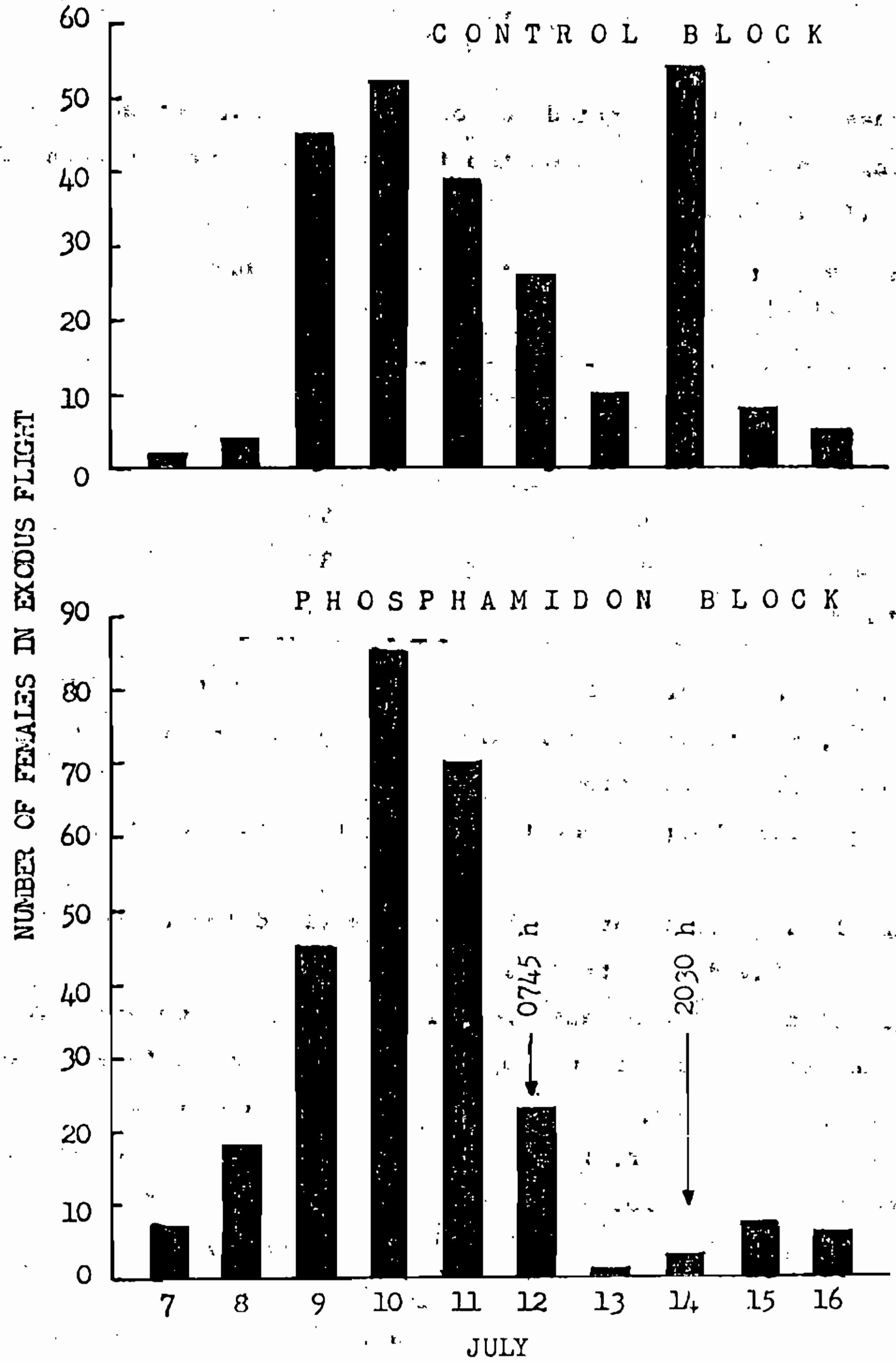

Fig. 2. Female activity on the control and spray blocks over a 10-day period that includes the two spray dates.

VII. POST-TREATMENT EGG COUNTS

E. G. Kettela

An egg-mass survey was carried out on the two treatment and one control block, using single branches from two fir and two spruce in each of 10 plots per block (Table 16).

Table 16. Results of egg mss survey on control and treated blocks

Block	Egg-mass counts per 10 ft^2 Fir	Spruce
Control	60	55
Phosphamidon	36	32
Fenitrothion	32	34

Thus, there were about twice as many egg masses in the control block as the treated blocks, but the relatively high egg population in the treated blocks leads to some critical questions:

(1) Were all the eggs laid by resident females before spray treatment in 12 July?

(2) Were some eggs laid by resident females that survived the treatment?

(3) Did gravid females invade the treated plots?

These questions cannot be answered directly because no pre-spray egg sampling was carried out. There did not appear to be a massive invasion of females into the spray blocks suggesting that most of the observed eggs were laid by resident females. However, it is of interest to note the calculated eggs per female on the control plot as an index of female movement:-

<u>CONTROL</u>: Female count/10 ft^2 = 5.7 (Greenbank)
<u>4.2</u> (Kettela)
= 5.0 (Mean)

Eggs/10 ft^2 = 1085

Eggs per female = 217

Long-term data indicate that a field population of 5.0 females per 10 ft^2 of foliage would be expected to lay about 90 eggs per individual and therefore the reproduction rate of 217 observed in the control block suggests some degree of invasion although the estimate of 217 is within the sampling error. Thus invasion may or may not have occurred in the treated plots.

Periodic checks must be obtained in future tests to determine the number of eggs laid in treated blocks and particularly their origin. If many of the 36 egg masses per 10 ft^2 in the Phosphamidon block were laid before spraying on 12, July, then the question of when to spray requires a critical evaluation.

VIII. SIDE EFFECTS OF SPRAY PROGRAM: MORTALITY OF ARTHROPOD PREDATORS AND PARASITES

G. N. Gesner and I. W. Varty

The 40 drop cloths that were set out in each treated block to measure budworm kill were also used to collect non-target victims such as adult parasites and immature and adult predators. These were tallied by taxa (species, generic, and family groups) according to our skills of identification. The counts in the accompanying tables represent the number of specimens collected daily in 20 'fir' drop cloths, 20 'spruce' drop cloths, and 10 'open' cloths (see Section III).

Fenitrothion Block

The tallies of parasites collected daily on the fenitrothion block are presented in Table 17. *Apanteles spp.*, mainly *A. fumiferanae* an important budworm parasite, was the most numerous taxon. It is obvious that the drop cloths were equally effective whether under spruce (1.20 *Apanteles* per ft^2) or fir (1.35 per ft^2), the adult parasites are equally distributed on the two hosts although the original host budworm were far more abundant on the fir. However, the drop cloth in the open collected 5.15 *Apanteles* adults per ft^2. Thus, in the fenitrothion block, the drop cloth in the open patches collected four to five times as many adults as cloths under conifer crowns. *Glypta fumiferanae*, another budworm parasite, was about twice as abundant in the open as under tree crowns. Other hymenopterous parasites were about three times more abundant on cloths in the open as under tree crowns. This distribution suggests to us that parasites suffer contact toxicity more frequently while foraging in ground cover (for sugar foods) than while searching trees for host larvae.

The host relationships of the "other braconids" and "other ichneumonids" in Table 17 are not known; these groups of parasites include many species and no doubt have many different hosts. The "other braconids" column includes one species, an *Ascogaster*, which was quite numerous; its host or hosts, evidently abundant, is unknown.

Fenitrothion caused immediate mortality which dwindled as the spray date receded. The second application was more damaging than the first, suggesting that treatments should be limited to a single application if possible.

The kill of predators is similarly recorded (Table 18). The various predators were mainly non-winged, and were therefore largely captive on their host trees, but small numbers of adult forms (mirids, anthocorids, ladybeetles, elaterids, and ants) had the capacity to be mobile between different kinds of vegetative cover. It is obvious that most predators were killed in the tree because the drop cloths in the open intercepted very few specimens. Also fir was a more copious source of killed predacious insects than spruce.

Predator mortality was greatest in the first collection after each spray, then diminished rapidly over the next 3 days. The high mortality after the second application again suggests that the treatment should be limited to one application to minimize losses of beneficial insects.

<u>Phosphamidon Block</u>

The tallies of parasites killed by Phosphamidon are given in Table 19. As in the fenitrothion block, *Apanteles spp.* were the most abundant victims - 2.84 per ft^2 under fir, 2.33 under spruce, and 3.63 in the open. The other taxa were present in roughly the same proportions as in the fenitrothion block. The dominance of the spruce budworm as the main host for the parasite complex available as adults in mid-July was again apparent.

Kill was greatest on the first day of collection after each application, and was slightly greater in the first application. However, it is probable that the second application took a higher proportion of the surviving parasites than the first.

Table 20 presents the mortality of predators. The spectrum of mortalities ran fairly evenly through the several insect taxa, but the most numerous victims were *Anatis mali* larvae and adults and *Balaustrium* mites. Roughly twice as many specimens were collected from fir as from spruce, and the "open" drop cloths were almost completely unproductive. The first application accounted for nearly two-thirds of the total mortality.

Attempts to convert the number of dead arthropods in drop cloths to populations per acre were subject to many biases. Very rough estimates based on the proportion of block covered by fir, spruce, and open spaces are shown in Table 21. The numbers are impressive and it is obvious that spraying in mid-July runs the risk of severely reducing populations of beneficial insects. It is also apparent that one application rather than two would be far less damaging to non-target organisms.

Table 21. Estimated numbers of budworm parasites and predators killed per acre in the fenitrothion and Phosphamidon blocks

Organism	Fenitrothion	Phosphamidon
Apanteles	96,922	121,533
Glypta	4,629	12,196
Meteorus	1,498	2,396
Pentatomids	7,895	3,921
Mulsantina	4,492	5,010
Anatis	5,309	16,335

Any major disturbance of the biocontrol mechanism is ecologically inadvisable in forest husbandry. From this experiment, however, we do not know the rate of survival of predators and parasites, only estimated mortality.

Rearings of budworm from each area were conducted in 1973 to test the persistence of *Apanteles* and *Glypta* nearly one year after treatment. The following results were obtained (Table 22).

Table 22. Per cent parasitism in spruce budworm populations on 14 June 1973, 11 months after insecticide applications.

Parasite species	Fenitrothion block		Phosphamidon block	
	fir	spruce	fir	spruce
Apanteles fumiferanae	1.6	3.2	4.1	7.7
Glypta fumiferanae	1.0	2.1	2.1	2.6
Total	2.6	5.3	6.2	10.3

These data show values of per cent parasitism which are low compared with the norms (20%) in unsprayed plots, but the reduction in the incidence of these parasites is not drastic. Survival in the Phosphamidon block is better than in the fenitrothion block. The results are encouraging with regard to the budworm/parasite relationship; but the soundness of adulticide treatments with regard to biocontrol mechanisms in the ecosystem at large remains untested.

Table 17. Numbers of adult parasites collected daily from drop cloths in various sites (10 plots) in the fenitrothion-treated block, mid-July 1972

Date (July)	*Apanteles*	*Meteorus*	Other Braconids	*Glypta*	Other Ichneumonids	Tachinids	Diptera larva	Diptera pupa	Total
				Balsam Fir					
12	4		1	1			5		11
13	28		4	1	5		1		39
14	1		2					3	6
15	59		7	3	3		3	1	76
16	16	1	2	1					20
17								1	1
19					1				1
Total	108	1	16	6	9		9	5	154
				Red Spruce					
12	4		3		3				10
13	18		9	3	2		3		35
14			1				6	1	8
15	57	2	12	3	2		3	3	82
16	17		5	1	1	1			25
17								2	2
19							1	3	4
Total	96	2	30	7	8	1	13	9	166
				Open					
12	15	2	8	2	2				29
13	61		24	2	8	1			96
14	3		3	1	3				10
15	102	1	18		6				127
16	19		17	2	1				39
17	6		1						7
Total	206	3	71	7	20	1			308

Table 18. Numbers of predators collected daily from drop cloths in various sites (10 plots) in the fenitrothion-treated block, mid-July 1972

Date July	Mirids	Antho-corids	Penta-tomids	Hemero-biids	*Muls-antina*	*Anatis*	Other Cole-optera	Syrph-ids	Formi-cidae	Spiders	Mites	Others	Totals
						Balsam Fir							
12	1			5	4	1	1	1	6			1	20
13	13	3	7	3	13	10	2	1	2	1		2	57
14	2	1	1		3	2	1	2			3		15
15	3	2	7	2	5	8		1	1		3	3	35
16			2		2	3					2	1	10
17			1			1	1		1	1			5
19							1						1
Total	19	6	18	10	27	25	6	5	10	2	8	7	143
						Red Spruce							
12			5			1	1		2	1			10
13	12	1	12	3	2	4	2		2	2		1	41
14	2										1		3
15	4		2	1	1				1	2	5	2	20
16	1		1	1							6		9
17													0
19													0
Total	19	1	20	5	3	7	3		5	5	12	3	83
						Open							
12			1									2	3
13	3		1						1				5
14		1											1
15	1						1						2
16													0
17													0
19													0
Total	4	1	2				1		1			2	11

Table 19. Numbers of adult parasites collected daily from drop cloths in various sites (10 plots) in the Phosphamidon-treated block, mid-July 1972

Date (July)	*Apanteles*	*Meteorus*	Other Braconids	*Glypta*	Other Ichneumonids	Tachinids	Diptera larva	Diptera pupa	Total
					Balsam Fir				
12	114	1	7	14	5	2	2	2	147
13	31		10	1	2		3		47
14	2			1			1		4
15	62	1	10	2	5	1	1		82
18	18		3	5	2		4		32
20									0
Total	227	2	30	23	14	3	11	2	312
					Red Spruce				
12	71		10	9	5	2		3	100
13	24		8	1	2		6	4	45
14	3		1	1		1	2		8
15	73	3	11	1	5	1	1		95
18	11		4	6	1		3	4	29
20	4						1	1	6
Total	186	3	34	18	13	4	13	12	283
					Open				
12	49		12	7	5				73
13	15	2	11						28
14	3		1	1					5
15	52	3	4	1	4				64
18	26	1	31	6	2				66
20									0
Total	145	6	59	15	11				236

Table 20. Numbers of predators collected daily from drop cloths in various sites (10 plots) in the Phosphamidon-treated block, mid-July 1972

Date July	Mirids	Antho-corids	Penta-tomids	Hemero-biids	*Muls-antina*	*Anatis*	Other Cole-optera	Syrph-ids	Formi-cidae	Spiders	Mites	Others	Totals
						Balsam Fir							
12	2	1	1	1	9	27	1		1		5	9	57
13	5	1	1		5	12	4	3	2		59	6	98
14		1	1	1	3		1	1			6	1	15
15	25	5	2	5		9		1		1	22	1	71
18	2		1			7		3		1	1		15
20						1				1			2
Total	34	8	6	7	17	56	6	8	3	3	93	17	258
						Red Spruce							
12			2	1		11	1		1	1	1	3	21
13	1		5	2	4	1	5				14	1	33
14	1		1		1						5		8
15	8	14	1	10		1	2	2	1	1	14	1	55
18			3	1	1	6			1			1	13
20													0
Total	10	14	12	14	6	19	8	2	3	2	34	6	130
						Open							
12												2	2
13	1							1				1	3
14				1						1			2
15												1	1
18										2			2
20												1	1
Total	1			1				1		3		5	11

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