EFFECTS OF PHOSPHAMIDON SPRAYS ON NON-TARGET

INSECTS IN FIR-SPRUCE FOREST,

SPRUCE BUDWORM ADULTICIDE TRIALS 1973

by

I. W. Varty and F. A. Titus

MARITIMES FOREST RESEARCH CENTRE

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ABSTRACT

The spectrum of arthropod mortality in response to aerial sprays of Phosphamidon against spruce budworm adults was determined by use of drop-trays. About 90% of the knockdown occurred in the two days after treatment. Drop-trays under trees collected twice as many arthropods as those in open sites. The major group of non-target victims was spruce budworm parasitoids; yet in spite of severe immediate kill at standard dosage treatment, percent parasitism in the next generation of hosts averaged 18%, which was satisfactorily high. Predaceous insects of many kinds were also poisoned by the spray but a single treatment did not threaten their survival. Mortality of predaceous arachnids was minor, probably less than 5%. Many of the other victims were adult insects present in the tree canopy but primarily associated with other forest and stream habitats.

Résumé

Les auteurs déterminèrent le spectre de mortalité des Arthropodes par suite d'arrosages aériens dans la lutte contre les adultes de la Tordeuse des bourgeons de l'Épinette. Pour ce faire, ils utilisèrent des plateaux à retombées. Environ 90% de la mortalité se produisit durant les deux jours qui suivirent l'arrosage. Les plateaux sous les arbres permirent de récolter deux fois plus d'Arthropodes que les plateaux à ciel ouvert. Il y avait surtout des parasitoïdes de la Tordeus; cependant, malgré qu'ils fussent tués en grand nombre, les parasites affectèrent en moyenne 18% des hôtes de la génération suivante, pourcentage satisfaisant. Il y avait aussi des insectes prédateurs de divers genres mais un seul traitement ne mit pas en danger leur survie. La mortalité des Arachnidés prédatrices se révéla basse, probablement moins que 5%. Plusieurs autres victimes étaient des insectes adultes présents dans le couvert forestier mais typiques surtout d'autres habitats forestiers ou des cours d'eau.

INTRODUCTION

It is generally conceded that natural ecosystems function with maximum stability and long-term productivity when normal faunal and floral diversity is maintained. One important function dependent upon species diversity is predation in the broad sense; when a full complement of predatory and parasitoid insects at normal densities operates within a system, the populations of most defoliator insect species are regulated at levels which do not threaten the survival of the host trees. Conversely, when natural control organisms are drastically reduced, irruptions of minor pests may damage crops.

Aerial application of insecticides for forest pest control invariably takes a toll of parasitoid and predaceous arthropods (Leonard 1971, Gesner and Varty 1973). However, we do not know whether such mortality to predators and parasitoids is drastic or minor; or whether affected populations can recuperate rapidly or be compensated for by responses of non-susceptible species with similar function.

In 1973 an experimental spray programme was conducted in northern New Brunswick to control spruce budworm, *Choristoneura fumiferana* (Clem.) in the adult stage. The effects of the insecticide on non-target organisms were monitored. The objectives of the study now reported were:- (1) to determine the spectrum of mortality of predators and parasitoids following applications of the organophosphate insecticide Phosphamidon at four dosages, and (2) to check the survival and recuperation of parasitoids specific to spruce budworm.

In insect community dynamics in forest stands, the immediate mortality of poisoned non-target insects is not in itself important. What does matter are the proportions of species populations surviving a given treatment; the persistence of a species in the face of perennial treatment, the recuperation of a species population after cessation of treatment, the interrelationships of species populations in a community, and the long-term functioning of community processes in the trophic web. This study is a step towards the understanding of the ecological responses of a natural system to insecticidal stress. It supports and amplifies the results of earlier studies on the side effects of Phosphamidon sprays against spruce budworm adults (Gesner and Varty 1973).

METHODS

The experimental spray programme was conducted by Forest Protection (N.B.) Ltd. and its effect on budworm moths was assessed by the Maritimes Forest Research Centre (*Kettela and Miller, personal communication). The test area was sited across the Madawaska-Victoria County line, east of St. Leonard, New Brunswick, and consisted of 340,000 acres of mixed woodland dominated by mature and middle-aged balsam fir, *Abies balsamea* L (Mill.) and red and white spruces (*Picea rubens* Sarg. and *P. glauca* (Moench) Voss (Fig. 1). In 1973 this tract had a heavy but variable spruce budworm infestation, but only a light hazard rating because defoliation was not heavy or extensive until 1972. In recent years this stretch of woodland has had no recorded insecticide treatment except for fenitrothion treatment (3 oz/acre 210g/ha) on 24,000 acres (F.P.L. blocks 73 and 74) on 18 June 1973 for budworm larvae.

*E.G. Kettela and C.A. Miller, Maritimes Forest Research Centre, Fredericton, N.B.
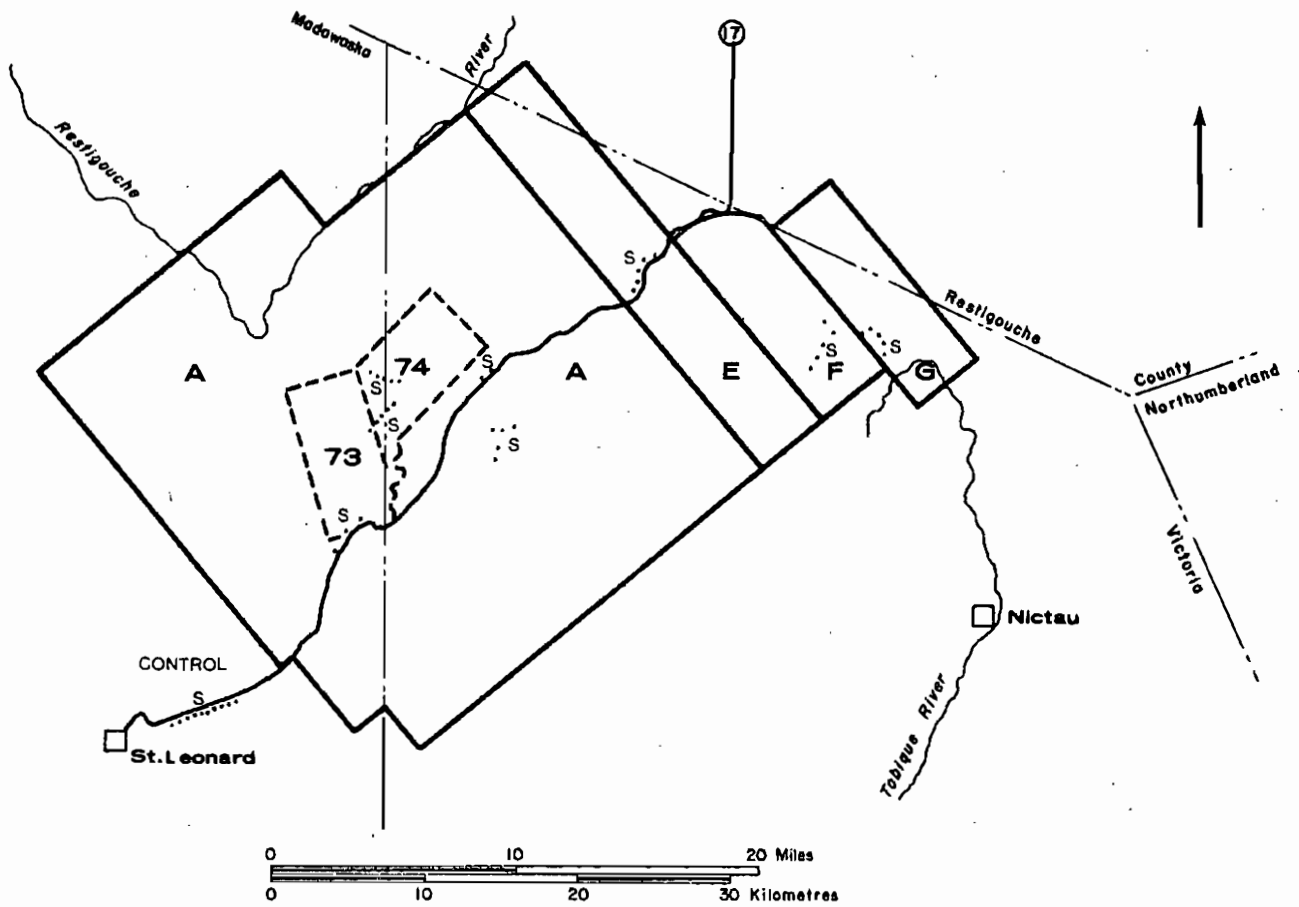
Fig. 1   Location of experimental block and sample plots in northern New Brunswick
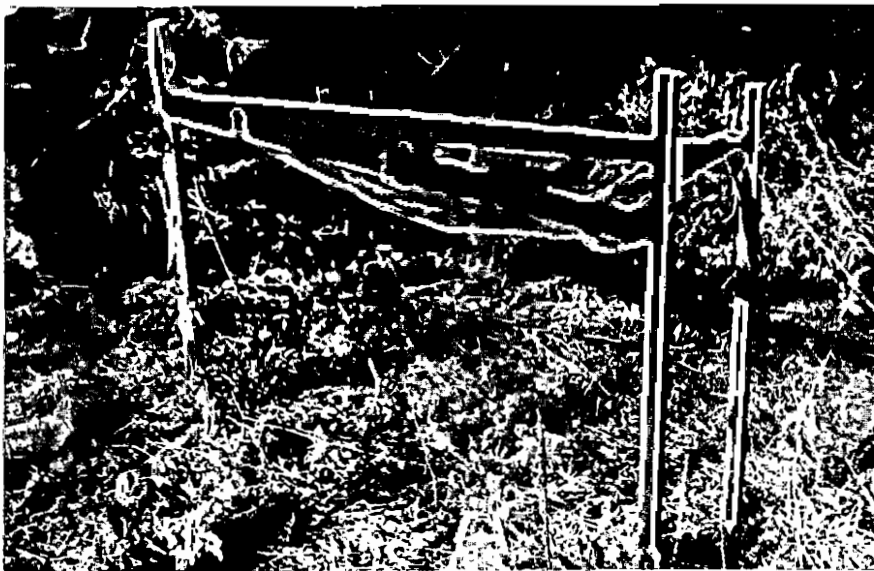

Fig. 2   Drop-tray in balsam fir site

All our plots were in rather similar middle-aged to mature stands with a composition of 50% fir, 20% spruce, 20% hardwoods, and 10% open patches. The allocation of the 35 plots was biassed to sample the main test dosage, 2 oz per acre; we used the same plots and collecting trays for non-target organisms as our colleagues used for tallies of dead moths.

The blocks and treatments were:

Block	Acreage	Phosphamidon/ac	Spray interval	Sample plots
A	240,000	2 oz	–	20
E	20,000	2 + 2 oz	29 hrs	5
F	20,000	0.5 oz	–	5
G	20,000	0.5 + 0.5 oz	4 hrs	5

The spectrum of arthropod mortality

Mortality from aerial sprays was tallied by use of drop-trays (Fig. 2), each with a collecting surface of 6.25 ft^2 (0.58 m^2), sited under the crowns of mature fir, white or red spruce, and hardwood trees (white birch, trembling aspen, red maple) or in the open patches. Each kind of site was sampled with equal effort, one tray per site. Poisoned insects were collected daily on 35 plots (= 140 trays) for four days following spray treatment, to determine the rate of toxicity. These tallies included insects which fell to the trays from responses other than insecticidal ones. However pre-spray observation of fallout showed the numbers of naturally-dying and live-falling arthropods are negligeable.

In block A, a special plot was established so that faunal survival following operational aerial spray could be measured. The plan was to knock out all the surviving insects by use of a second, ground-based mistblower insecticidal spray at "overkill" dosage on 13 July, four days after the aerial spray. Insects were collected one day after the mistblower treatment. The sum of the post-aerial-spray and post-mistblower-spray collections represents the total density before treatment began.

We were not entirely satisfied with the efficacy of the trays for collection of poisoned insects. Some trays were riffled by wind that may have carried away some specimens; others were raided by birds and damaged by large mammals. Moreover, the concept may be intrinsically imperfect for collection of parasitoid adults and some winged predatory insects, since the tray collects only those insects which are confined to the space above the tray. We have observed that many parasitoids spend much time foraging for food (nectar) in ground herbage below the tray level; Townes (1958) believed that ichneumonids spend several hours per day searching the foliage of trees and shrubs with small nectaries. If disabled by insecticide while so occupied, their bodies might not be intercepted by the trays. Thus there is a probability that drop-tray tallies substantially under-represent the mortality of parasitoids, and of predators to a lesser extent.

The survival of parasitoids attacking spruce budworm was estimated by measurement of percent parasitism in large host samples, mainly from Blocks A and E. Immature budworms were collected at random

in sample plots from fir and spruce trees in late June (pre-spray sample
of small-larval parasitoids), in early July (pre-spray sample of large-
larval and pupal parasitoids) and in early November (post-spray sample
of small-larval parasitoids). The hosts were reared in the laboratory
in diet creamers, for the expression of percent parasitism in the
various test blocks.

The comparison of pre-spray and post-spray percent parasitisms
provides a lead to the population response of individual species. It is
only a crude measure, as it is not related to absolute populations per
acre. However it is the only method practicable when sampling resources
are small.

We had intended to measure populations of predators and
parasitoids in July 1974, one year after treatment, to estimate recuper-
ation. Yet we opted to abandon these plots because the experimental
spray programme could not be isolated from unmonitored insecticide
usage. Unregistered spraying by the owners of the woodland in June/July
1973 casts doubt on the validity of comparisons among the four experi-
mental dosages, and further unmonitored treatment of the district took
place in spring 1974. Thus the arthropod fauna did not have an interval
of undisturbed recuperation.

RESULTS

Effect on parasitoid insects: drop-tray studies

In the 4 days post-spray, drop-trays collected 1230 parasitoids
in all four vegetational sites: of the total collection, 37% were taken

under spruce, 29% under fir, 20% under hardwoods and 14% in open sites
(Table 1), with equal sampling effort. The rate of fall of parasitoids
was greatest on the first day (76%), and decreased through the second
day (16%) to the third and fourth days (8%). Previous experience
(Gesner and Varty 1973) had shown that collections after the fourth day
were insignificant. The site of the drop-tray did not influence the
rate of fall over time.

Table 1. Numbers of parasitoids collected on 140 drop-trays (35 plots x
4 sites) over a 4-day period after Phosphamidon spray at
various dosages (combined value for blocks A, E, F, and G.)

Site	Post-spray			Totals
	Day 1	Day 2	Day 3+4	
under spruces	355	62	41	458
under fir	250	59	36	355
under hardwoods	185	45	24	254
in open sites	144	26	3	173
Totals	934	192	104	1,230

The knockdowns by dosage of insecticide are compared in Table
2. The specific budworm parasitoid *Apanteles fumiferanae* Viereck was by
far the most abundant victim (80% of all killed parasitoids), and *Glypta*
fumiferanae (Vier.) was next most abundant (8%). The remaining 12% com-
prised many species from many hosts. They included the ichneumonids
Lissonota parvus (Cress.), *Diadegma conodor* (Vier.) *Aoplus ruficeps*
vagans (Prov.), and *Acropimpla pronexus* Townes; the braconids *Macrocentrus*

Table 2. Densities of dead parasitoid adults collected per ft^2 (0.093 m^2) in the 4-day period post-spray

Site	Parasitoid	Phosphamidon oz/ac			
		Block A 2	E 2 + 2	F 0.5	G 0.5 + 0.5
bF	*Apanteles fumiferanae*	.83	2.94	1.31	1.41
	Other braconids	.10	.10	.06	.06
	Glypta fumiferanae	.07	.22	.29	.22
	Other ichneumonids	.06	.29	.06	–
	Tachinids	–	–	–	–
	Totals	1.06	3.55	1.72	1.69
rS/wS	*A. fumiferanae*	1.14	1.63	2.14	3.58
	Other braconids	.14	.16	.03	.03
	G. fumiferanae	.11	.06	.19	.29
	Other ichneumonids	.12	.13	.06	.19
	Tachinids	.02	.03	–	–
	Totals	1.53	2.01	2.42	4.09
Hw	*A. fumiferanae*	.74	1.44	.64	.77
	Other braconids	.06	.16	.06	.06
	G. fumiferanae	.10	.10	.10	.06
	Other ichneumonids	.13	.22	.10	.10
	Tachinids	–	–	.03	.06
	Totals	1.03	1.92	.90	1.05
Open	*A. fumiferanae*	.62	.74	.74	.67
	Other braconids	.02	.13	.06	–
	G. fumiferanae	.04	.10	.03	.10
	Other ichneumonids	–	.13	–	.03
	Tachinids	.01	–	–	–
	Totals	.69	1.10	.83	.80

iridescens French., *Chelonus recurvariae* McComb, *Meteorus trachynotus* Vier., and *Ascogaster argentifrons* Prov.; and the sarcophagids *Agria housei* Shew., and *Sarcophaga* sp. The spectrum of species is very dependent upon spray date; a week earlier or a week later would substantially change the vulnerability of some species.

Table 2 does not offer an estimate of the rate of parasitoid mortality as a proportion of the population pre-spray, and therefore does not reveal the efficacy of the four insecticide dosages.

However, in our experience a severely-infested mature fir-spruce stand would usually produce budworm parasitoids to a peak density of 2 to 8 adults per ft^2 of stand area, i.e. the column of space above 1 ft^2 of soil; most of these would be actively flying in early July. It is probable that such high densities of parasitoids were attained in blocks F and G, which had high budworm counts, about 20 per ft^2 of stand area. The abundance of parasitoid adults may have been considerably lower in our plots in A and E blocks which had budworm densities about half those of F and G. In all plots the knockdown represented a substantial fraction of the total parasitoid population.

To check on survival, a special plot with 16 drop-trays was established in block A. Four days after the 2 oz operational spray by aircraft, we applied a drenching "overkill" treatment (Phosphamidon) by ground-based mistblower. The object was to knock down all parasitoids which had survived the operational treatment. The dead parasitoids were collected one day later. It is assumed that the original tallies from the aerial spray plus the tallies from the mistblower spray would account for the total vulnerable population present just before control operations began. Table 3 lists the densities of parasitoids killed in the

Table 3. Knockdown of parasitoids in one block A plot following
(a) aerial spray at 2 oz Phosphamidon/acre, 9 July, and
(b) mistblower spray at "overkill" dosage, 13 July

| Site | Parasitoids | (Density per ft^2 (0.093 m^2) from 4 drop-trays per site) | | |
		(a)	(b)	Total
bF	*A. fumiferanae*	2.71	.25	2.96
	Other braconids	.05	.05	.10
	G. fumiferanae	.41	.15	.56
	Other ichneumonids	.10	.05	.15
		3.27	.50	3.77
rS/wS	*A. fumiferanae*	2.10	.10	2.20
	Other braconids	.21	—	.21
	G. fumiferanae	.21	.10	.31
	Other ichneumonids	.10	.16	.26
		2.62	.36	2.98
Hw	*A. fumiferanae*	1.18	.25	1.43
	Other braconids	.10	—	.10
	G. fumiferanae	—	—	—
	Other ichneumonids	.25	.05	.30
		1.53	.30	1.83
Open	*A. fumiferanae*	.54	—	.54
	Other braconids	—	.08	.08
	G. fumiferanae	—	.08	.08
	Other ichneumonids	—	—	—
		.54	.16	.70

two successive sprays, and suggests that a very large fraction was eliminated by the first treatment. In applying these mortality rates to stand composition with 50% fir, 20% spruces, 20% hardwoods, and 10% open, we estimate that 85% of the initial parasitoid population were killed by aerial spray at 2 oz Phosphamidon per acre.

We can only speculate on percentage mortality in the other blocks. Our guess is that the most severe effect occurred in the 2 + 2 oz spray in block E. When we applied our mistblower treatment to the trees over a single group of 4 drop-trays, not a single parasitoid was knocked down. We might infer that the aerial spray had eliminated virtually 100% of parasitoids in advance of the mistblower treatment, but our sample was too small to offer confidence in that inference. The kill effected in blocks F and G (0.5 oz and 0.5 + 0.5 oz/acre, simulating drift) may have been a relatively low percentage.

Pre-spray status of parasitism of spruce budworm
and post-spray recuperation

Our original intention was to determine percent parasitism by rearing host larvae pre-spray, and to compare with post-spray parasitism at a comparable time in the following year.

In fact, we were able to compare only blocks A and E in this way. Table 4 lists percent parasitisms from samples gathered on 21 June (representing small-larval parasitism) and 6 July 1973 (representing large-larval and pupal parasitism. The data indicate that

Table 4. Occurrence of parasitoids in rearings of immature spruce budworm
collected in blocks A and E (pre-spray, spring 1973)

Block	Date Sampled	Budworm rearings	Parasitoids reared					Total	% Parasitism
			*Af	Gf	Mt	Ll	P		
		from fir							
A	June 21	566	59	40	–	3	–	102	18.0
	July 6	793	–	1	7	15	4	27	3.4
E	June 22	195	30	4	–	3	–	37	19.0
	July 6	202	–	–	2	16	–	18	8.9
		from spruces							
A	June 21	391	21	9	–	1	–	31	7.9
E	July 6	646	–	–	7	12	4	23	3.6
E	June 22	186	7	3	–	2	–	12	6.5

* Af = *Apanteles fumiferanae*,   Ll = large-larval parasitoids

   Gf = *Glypta fumiferanae*,   (mainly *Actia interrupta*),

   Mt = *Meteorus trachynotus*,   P = pupal parasitoids (mainly

                                         Phryxe pecosensis)

blocks A and E were reasonably comparable in parasitoid abundance and species distribution pre-spray, at least in our sample plots.

Post-spray rearings of budworm from the various treatments were conducted in spring 1974 (Table 5). It is evident that small-larval parasitism persisted in all blocks at rates within the norms for New Brunswick. However, in comparing pre- and post-spray values in blocks A and E (Tables 4 and 5) there is evidence that *A. fumiferanae* (= Af) (which suffered heavy casualties from insecticide) had ceded dominance to *G. fumiferanae* (= Gf) (which did not suffer heavy mortality), as follows:

	% parasitism in fir only			
	Block A		Block E	
	Af	Gf	Af	Gf
1973 (pre-spray 1 month)	10.4	7.1	15.4	2.1
1974 (post-spray 10 months)	7.7	14.4	6.0	16.1

Thus *A. fumiferanae* was less influential in budworm dynamics after insecticidal treatment than before, but this reduction was more than balanced by the increased rate of parasitism by *G. fumiferanae* in post-spray budworm populations. It is not known whether there is competition between *A. fumiferanae* and *G. fumiferanae* which would lead one species to compensate for diminished status of the other. One other feature of Table 5 is the remarkably high percent parasitism (38%) in the control (untreated) area, which has never had insecticidal treatment. These data do not imply that parasitism is much higher in untreated areas than in treated areas, i.e. cause and effect. They do show that in favourable habitats the numerical response of both parasitoids to abundant budworm hosts can be much higher than the norms, that is, there is potential for manipulation of parasitism.

Table 5. Occurrence of small-larval parasitoids reared from spruce
budworm larvae from balsam fir, in spring 1974 (post-spray
10 months).

Block	Budworm rearings	Af	Gf	Other spp.	Total	% parasitism
A	548	42	79	-	121	22.1
E	149	9	24	-	33	22.1
F	213	11	12	-	23	10.8
G	184	20	14	-	34	18.5
Control	459	109	65	2	176	38.3

Table 6. Numbers of predaceous arthropods collected on 140 drop-trays
over the 4-day period following aerial spray with Phosphamidon
(pooled dosages).

	Site	Post-spray day 1	day 2	day 3+4	Totals
Insects:	under spruces	101	20	14	135
	under fir	45	10	14	69
	under hardwoods	23	5	4	32
	in open sites	11	-	-	11
Arachnids:	under spruces	31	10	6	47
	under fir	27	6	2	35
	under hardwoods	16	2	4	22
	in open sites	4	4	-	8
	Totals	258	57	44	359

Values of percent parasitism change unpredictably, so it
is difficult to reach firm conclusions. However from this experiment it
appears unlikely that the function of parasitism in relation to spruce
budworm is adversely or irretrievably affected by single dosages of
Phosphamidon at 2 oz or less per acre.

Effect on predaceous arthropods: drop-tray studies

The knockdown of predaceous arthropods (Table 6) after in-
secticide application was greatest under spruce (51% of total predators
killed), then fir (29%), hardwoods (15%) and least in open sites (5%),
given equal sampling effort with drop-trays. This differs from the 1972
adulticide programme in which fir sites were twice as productive as
spruce sites. The difference between the two years is readily expli-
cable; on fir, predator populations respond to the abundance of the prey
aphid *Mindarus abietinus* Koch, which was plentiful in 1972 and scarce in
1973.

The daily rate of fall of predators after spray application
was similar in tallies of both predators and of parasitoids: 72% of the
predaceous arthropods fell on the first day, 16% on the second, and 12%
on the third plus fourth days.

The densities of killed predators are listed by taxonomic
category and insecticide dosage in Table 7. The chief victims, listed
in order of numerical frequency were mirids, ladybeetles, spiders,
mites, elaterid beetles, staphylinid beetles, ants, lacewings, syrphids,
pentatomids, anthocorids, nabids and phalangids. These predators have

Table 7. Density of predators killed per ft^2 of drop-tray in the 4-day period immediately after Phosphamidon spray at four dosages

Dosage in oz/ac	Block A 2		E 2 + 2		F 0.5		G 0.5 + 0.5	
	fir	spr	fir	spr	fir	spr	fir	spr
Miridae	.11	.05	.25	.13	.13	.35	.10	.83
Hemerobiidae	–	.01	.03	.13	.03	–	–	.03
Coccinellidae	–	.03	–	.10	.22	.35	.13	.51
Other Coleoptera	.07	.06	.06	.10	.10	.35	.16	.22
Syrphidae	.01	.02	.03	–	–	.03	–	–
Formicoidea	.02	.03	.16	.13	–	.03	–	–
Araneae	.07	.14	.10	.29	.16	.10	.10	.13
Acari	.04	.10	.10	–	.06	–	.06	.03
Totals	.32	.44	.73	.62	.70	1.21	.55	1.75

	Hw	Open	Hw	Open	Hw	Open	Hw	Open
Miridae	.05	.01	.06	.03	.06	–	.03	.10
Hemerobiidae	.01	–	–	–	.03	–	–	–
Coccinellidae	–	–	–	–	–	–	–	–
Other Coleoptera	.09	.03	.06	.03	–	–	.03	–
Syrphidae	.02	.02	–	–	.03	–	–	–
Formicoidae	.02	–	.06	–	–	–	.03	–
Araneae	.06	.02	.03	.03	.10	–	.06	–
Acari	.02	.02	.03	.03	–	–	.03	.03
Totals	.27	.10	.24	.12	.22	–	.18	.13

low prey specificity, and are believed to be important factors in insect community dynamics and in ecosystem homeostasis. They exercise a light restraint on budworm abundance in the egg and small-larval instars, but have virtually no importance in the survival of large-larval budworms, pupae or adults.

Since we do not know the initial or final densities of survivors in the crowns, Table 7 tells us very little about the relative potencies of the four dosages. The kill in the heavily-treated blocks A and E was lighter than expected, relative to our former experience. Note that in 1972 the 2+2 oz dosage produced a total predator kill of $3.2/ft^2$ for drop-trays under fir and $1.6/ft^2$ under spruce, which is about 3 times the density of kill in block E, 1973. There is another anomaly in blocks A and E; the absence of dead specimens of *Anatis mali* auct. and the scarcity of *Mulsantina hudsonica* Casey, the two principal ladybeetles of fir-spruce forest, were unexpected because both are sensitive to Phosphamidon. One possible explanation may be that private spray operations in the vicinity of our plots' had already killed these ladybeetles and other predatory insects before we set up our drop-trays.

Another explanation for the low kill of predators in block A might be that the 2 oz dosage was relatively impotent or that deposits in the canopy were unusually low. Kettela and Miller evaluated the 2 oz treatment as the least effective against budworm moths; their conservative estimate was "well over 50% kill". To check survival of predaceous arthropods in block A, a special check plot was established with

Table 8. Knockdown of predaceous arthropods in one plot in block A following (a) aerial spray at 2 oz/ac 9 July (b) the successive mistblower spray at overkill dosage, 13 July (Numbers of insects represent total collection per 4 drop-trays at each site)

Predators	(a)	(b)	Total	(a)	(b)	Total
	under fir			under spruces		
Miridae	–	8	8	–	2	2
Hemerobiidae	–	–	–	–	1	1
Coccinellidae	1	3	4	3	–	3
Other Coleoptera	1	2	3	1	2	3
Syrphidae	–	3	3	–	3	3
Araneae	5	6	11	3	4	7
Acari	2	1	3	–	3	3
Totals	9	23	32	7	15	22
	under hardwoods			in open sites		
Miridae	1	2	3	–	–	–
Syrphidae	–	2	2	–	1	1
Araneae	–	4	4	–	–	–
Acari	–	1	1	–	–	–
Totals	1	9	10	–	1	1

16 drop-trays and treated to an "overkill" dosage of Phosphamidon by mistblower, 4 days after the aerial spray operation. This eradication treatment knocked down a relatively large number of survivors. It indicates that the original aerial spray poisoned only one quarter of the vulnerable population (Table 8).

Mortality of other non-target insects

In addition to the 1230 known parasitoids and 359 arboreal predators, we counted 2696 other non-target insects in the collections from drop-trays in blocks A E F and G (Table 9). Such raw counts do not have much biological significance in terms of ecosystem function, but they do indicate that the spectrum of insect toxicity of Phosphamidon at light dosages is very wide. This collection included scores or even hundreds of species, and at least 15 orders. The order with most individuals was Diptera, about 37% of the total. Most of the other victims were Homoptera, Lepidoptera and Hymenoptera. About one-third of the dead insects were winged adults not directly dependent upon the crown zone for their trophic needs; they included large groups primarily associated with streams, the soil, dead vegetation, and ground flora, so the impact of their death would reach almost every ecological niche. Only three wild bees were collected from drop-trays, so the function of pollination may have been little affected, unless drop-trays are a poor way of collecting poisoned bees.

Table 9. Numbers of arthropods collected from 140 drop-trays over a
          4-day period (pooled treatments)

Order	Individuals	Role
Plecoptera	17	Aquatic predators
Neuroptera	10	fir-spruce predators
Mecoptera	13	soil predators
Homoptera	436	arboreal sap suckers
Heteroptera	98	mostly arboreal predators
Lepidoptera (excl. budworm)	403	defoliators
Hymenoptera − sawflies	52	arboreal defoliators
− ants	22	predators, scavengers
− ichneumonoids	1213	parasitoids
− chalcidoids, cynipoids and proctotrupoids	125	mostly parasitoids, some gall makers and seed eaters
Coleoptera	162	various; some predators
Diptera − nematoceran	565	various
− brachyceran	125	various
− cyclorrhaphan	901	various
Other Insecta	35	various
Araneae	69	arboreal predators
Acari	34	arboreal predators
Non-target arthropods: total	4280	
Spruce budworm adults	6296	

Approximately equal proportions of the total catch were taken under the three tree sites, but open sites were much less effective (ratio 3:3:3:1). The densities of catch, pooled from all sites but excluding parasitoids and predators, were modest: about 6 per ft^2 in the E plots and about 2 per ft^2 in the A plots. Once again, we do not know the proportion of survivors.

DISCUSSION AND CONCLUSIONS

The methodology of ecosystem surveillance apropos insecticide spray programmes in forests is not well developed, but our use of drop-trays to monitor the side effects on the insect fauna of fir-spruce forests has led to a useful approach. Our attempt was hampered by limitations of manpower resources and weaknesses in research design. There is a perennial problem in coping with treatment decisions tailored to spray operations rather than research needs. Too few plots and too few trays were established to offer reliability to the data in a sampling universe that is notorious for its variability. Not only are the fauna and flora variable so that it is hard to standardize sampling plots, but the deposit of insecticide from any one treatment is highly variable. In any one plot the amount of deposit may vary from nil to several-fold the average over the whole target area. It follows that many plots should be established to counter this variability because it is generally impracticable to actually determine the quantity of deposit itself.

Sites under trees were about twice as productive of parasitoids as open sites. This conflicts somewhat with the trial in 1972 (Gesner and Varty 1973) in which open sites were more productive than fir and

spruce. However drop-trays in 1972 were set closer to the ground than in 1973, and may have been more efficient in collecting low flying parasitoids on forage missions. We conclude that all types of vegetational cover should be sampled in proportion to stand composition. Trays should be placed as low as possible.

Nevertheless we have observed that Phosphamidon at all dosages from 0.5 oz to 2 + 2 oz/ac applied in early July is toxic to a wide spectrum of parasitoid insects, predaceous arthropods, and other non-target insects in tree crowns. The parasitoids attacking the small-larval stages of spruce budworm were used as indicators of the general influence on parasitism. It was observed that the mortality of these two principal parasitoid species was quite severe in all treatments, yet post-spray recuperation of percent parasitism was very satisfactory. It appears that even the 2 + 2 oz/ac dosage does not result in near-eradication of the next generation.

As to the myriad other parasitoid species, the drop-tray method tells us little about the significance of insecticidal kill in terms of general parasitism within the insect communities. We suggest that the best way would be to pick other indicator host/parasitoid relationships, of necessity those which are easy to sample, and to embark on life-table studies. It is possible that particular parasitoid species may be acutely stricken by Phosphamidon usage, and that damage in certain niches of the ecosystem may be severe, but not yet detected. There are doubtless many parasitoid species exercising key-factor regulation of certain pests, pollinators, decomposer insects, fungus-browsers, etc. The population instability of such influential links in the trophic chain could result in covert degrade of resource productivity.

The function of predation may be more resilient. Most predaceous arthropods are catholic in diet, choosing various prey species according to the vagaries of availability. Thus if one predator species were diminished in population through hypersensitivity to insecticide, then another less susceptible or less vulnerable predator species might compensate by partially occupying the trophic niche of the extirpated predator. The drop-tray method of detecting mortality lends itself to the testing of that hypothesis.

The current report establishes some baselines against which the effectiveness of Phosphamidon in future spray programmes may be measured. Unfortunately, as explained earlier, the experimental area at Boston Brook does not lend itself to continued long-term studies of the impact of adulticide sprays upon the functioning of population processes.

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