by C. David Fowle

Effects of phosphamidon on forest birds in New Brunswick

Canadian Wildlife Service Report Series Number 16

Effects of phosphamidon on forest birds in New Brunswick

by C. David Fowle

Canadian Wildlife Service
Report Series–Number 16

Issued under the authority of the
Honourable Jack Davis, P.C., M.P.
Minister of the Environment

John S. Tener, Director
Canadian Wildlife Service

Available by mail from
Information Canada, Ottawa,
and at the following
Information Canada bookshops:

Halifax
1735 Barrington Street

Montreal
1182 St. Catherine Street West

Ottawa
171 Slater Street

Toronto
221 Yonge Street

Winnipeg
393 Portage Avenue

Vancouver
657 Granville Street

or through your bookseller
Price $1.00, Catalogue No. CW 65-8/16
Price subject to change without notice
Information Canada, Ottawa, 1972

Design: Gottschalk+Ash Ltd.
Cover photo by Ed Rayner

Contents

List of tables

Biography

C. David Fowle is acting director of the Centre for Research on Environmental Quality, York University, Toronto, and a professor of biology at Vanier College of the same university. He joined York University when it was founded in 1960 and served three years as chairman of the Department of Biology. He was biologist-in-charge of wildlife research for the Ontario Department of Lands and Forests for the previous 13 years and special lecturer in wildlife management at the University of Toronto for 14 years.

Dr. Fowle is a graduate of the universities of British Columbia and of Toronto.

Acknowledgements

I am indebted to many people for assistance with this project. F. G. Cooch and J. A. Keith of the Canadian Wildlife Service and staff of the Department of Fisheries and Forestry (now Department of the Environment) laboratory in Fredericton, especially R. Macdonald and E. J. Katella, all generously gave encouragement and assistance.

The staff of Forest Protection Ltd., especially B. W. Fleiger and B. A. MacDougall, encouraged my work in many ways, providing facilities, equipment and advice.

S. A. Teeple and P. Pearce of the Canadian Wildlife Service and students M. Jackson, B. Cook, R. S. Gibbon, F. Boehm, S. Lunn, T. McCaul, S. Robinson, R. MacLean, K. Childe and M. Lapp all helped in the field. Miss J. Cordingley assisted in running tests on captive birds and in other laboratory procedures and Miss L. Burton helped with the bibliography and data compilation.

Perspective

The research reported here was undertaken when replacements for DDT and other organochlorine insecticides were being sought. The organophosphate compounds, of which phosphamidon is one, appeared to be promising candidates. As little was known of how these newer insecticides would affect birds, it was important to assess the one which might be used over millions of acres of New Brunswick forests.

Abstract

The effects on birds of the operational use of phosphamidon in a spruce budworm control program in the forests of New Brunswick were assessed. Emissions from spray aircraft of greater than 0.25 lb./acre (0.28 kg/hectare) may be hazardous to birds, especially with fine atomization of the spray. Field observations and experiments with captive birds confirmed that lethal or intoxicating doses may be absorbed through the feet from sprayed vegetation or may be ingested. The oral lethal dose for small forest birds seems to lie between 1 and 3 mg/kg.

Résumé

Nous avons déterminé les effets sur les oiseaux de l'utilisation du phosphamidon, dans le cadre d'un programme de lutte contre la tordeuse des bourgeons de l'épinette dans les forêts du Nouveau-Brunswick. Les oiseaux sont affectés par des vaporisations aériennes dépassant 0.25 lb à l'acre (0.28 kg/ha), surtout si les particules sont très fines. Nous avons constaté, par des observations sur le terrain, comme par des expériences sur des oiseaux captifs, que des doses mortelles ou intoxicantes peuvent être ingérées ou absorbées par les pattes sur des plantes vaporisées. Pour les petits oiseaux des bois, la dose mortelle par voie orale semble se situer entre 1 et 3 mg/kg.

Conifer forest on the Green River watershed, New Brunswick. It was here that the spruce budworm was first detected in epidemic numbers in the late 1940's. Photo by Canadian Forestry Service.

Introduction

In 1964, phosphamidon[1] (2-chloro-2-diethylcarbamoyl-1-methylvinyl-dimethyl phosphate) was applied from the air on about 161,000 acres (65,150 hectares) of New Brunswick forest as part of a control program for spruce budworm (*Choristoneura fumiferana*). After application at a rate of 0.45 lb. in 0.75 U.S. gallons (USG) of water per acre[2], a number of forest birds were killed or disabled (Fowle, 1965). Between 1965 and 1968 I conducted additional experiments to confirm the observations of 1964 and to test the effects of lighter doses applied in various ways.

The field work in 1965 extended from late April to the end of July and was carried out from Parker Ridge, about 5 miles west of Boiestown in central New Brunswick. In the next 3 years the field season was approximately the same, but the headquarters was moved to Blackville, about 45 miles east of Parker Ridge, in 1966, back to Parker Ridge in 1967 and to Upper Blackville in 1968. The study area lay in the Eastern Lowlands Section of the Acadian Forest Region described by Rowe (1959) and in the Maritime Lowlands Ecoregion classified by Loucks (1962). The region is mainly coniferous with deciduous hardwood stands scattered in the western portion. Red spruce (*Picea rubens*), black spruce (*P. mariana*), balsam fir (*Abies balsamea*), red maple (*Acer rubrum*), white pine (*Pinus strobus*) and a few hemlock (*Tsuga canadensis*) form the characteristic forest association on the flat terrain of stony clay loams and sands. Scattered stands of beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*) and yellow birch (*Betula lutea*) are found on the higher ground. Red maple, wire birch (*Betula populifolia*) and aspen (*Populus tremuloides* and *P. grandidentata*) are common as fire types, except on some sandy areas where jack pine (*Pinus banksiana*) grows densely. Almost pure stands of black spruce characterize some extensive bogs. Most of the area is strongly dissected by rivers and tributary streams. Fowle (1965) gives the composition of seven sample plots in the region.

A wide variety of birds inhabit the forest (Squires, 1952; Morris *et al.*, 1958). Thirty to 40 species are common and an almost equal number is less frequent. Measurements of breeding density have not yet been completed, but estimates made during this study indicate a summer density of 160 to 180 breeding pairs per 100 acres (40.5 hectares) in summer (Wilson, 1968).

The field work was planned and carried out in co-operation with Forest Protection Ltd., the company responsible for the budworm control program, and representatives of various government agencies concerned with assessing the effects of the spraying. The large-scale operational experiments were designed to provide information of interest to sprayers, entomologists and fish and wildlife biologists. Thus the plots were located and treatments selected to suit a variety of requirements rather than the limited interest of the study.

The initial experimental design in 1965 included nine plots, of about 21 square miles each (about 13,000 acres or 5,200 hectares), and one control in an area of heavy budworm infestation lying between the southwest Miramichi River and the Gaspereau River in the Cains River watershed. But as field work progressed we modified the design, adding plots to test new ideas arising in the field or to check results of first applications. In the end we were able to obtain data from 16 plots and a control. Figure 1 shows their distribution, Table 1 their spray and censusing histories.

The objective was to test the effects of the following:

1. Varying amounts of phosphamidon sprayed from aircraft (0.25 and 0.5 lb./acre).
2. Varying dilutions with water (0.2, 0.4, 0.5 USG/acre).
3. Spraying early in the season versus late in the season.
4. The surfactant Invadine JFC[3].
5. Two applications.

[1]Trade name Dimecron, registered by CIBA Ltd.
[2]1 lb./acre = 1.12 kg/hectare.
1 USG = 3.785 litres.

[3]Registered trade name, CIBA Ltd.

Figure 1. Location of plots in 1965 and 1968

Figure 1

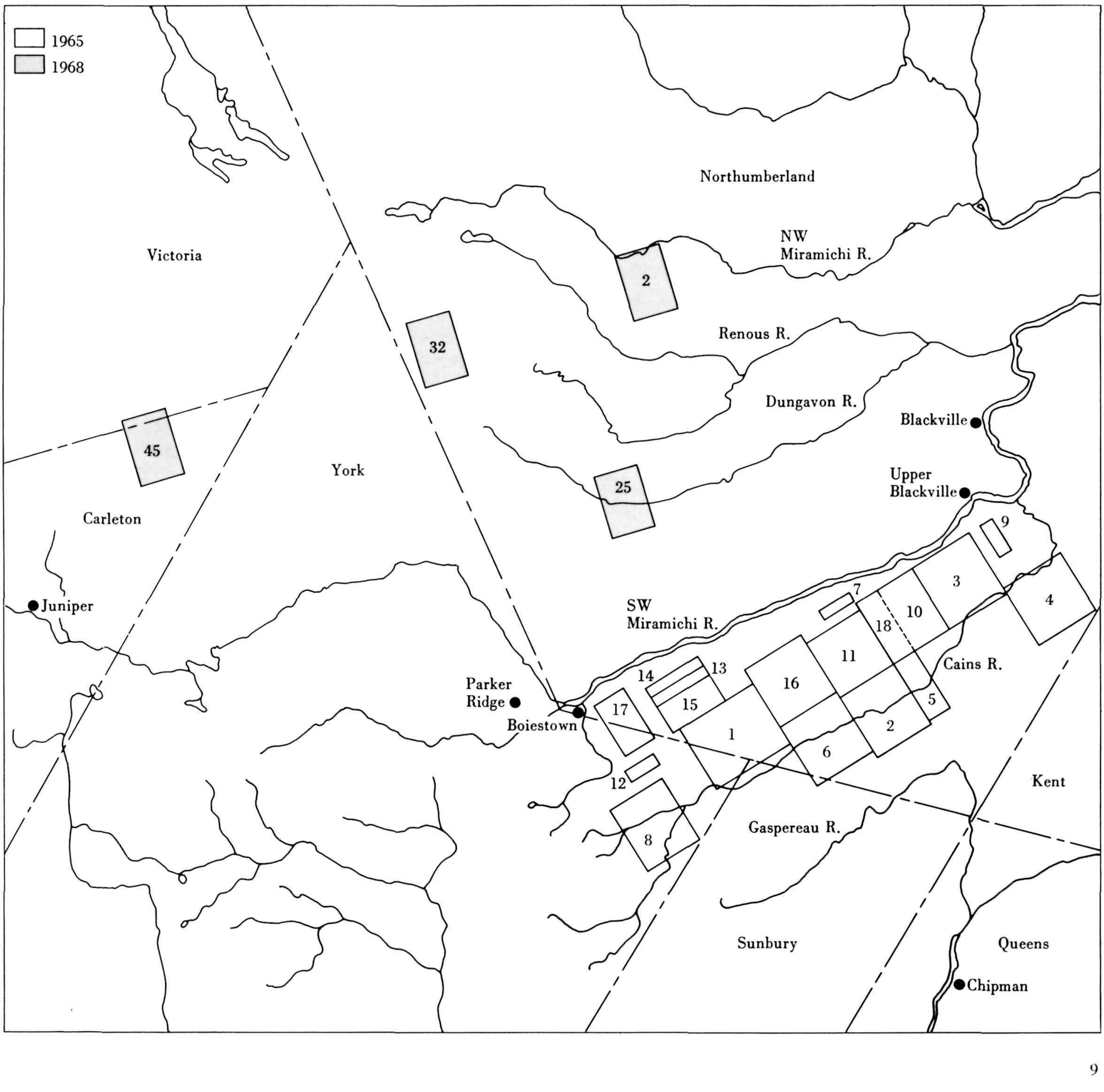

Table 1
Summary of spray and censusing history on experimental plots, 1965

Plot No.	Phosphamidon emitted lb./acre	Invadine included	Dilution USG/acre	Date and time sprayed	Censuses Pre	Censuses Post	Results
1	0.25	Yes	0.2	May 16, AM	7	3	Reduced ruby-crowned kinglets (*Regulus calendula*), myrtle warblers (*Dendroica coronata*); sick robins (*Turdus migratorius*), white-throated sparrows (*Zonotrichia albicollis*)
2	0.25	Yes	0.8	May 16, PM	8	4	Reduced ruby-crowned kinglets, myrtle warblers; 1 sick myrtle warbler picked up
3	0.25	Yes	0.8	May 19, PM	6	1	Rained out—no useful data
4	0.25	Yes	0.8	May 21, PM May 25, AM	0	0	No sick or dead birds found (May 22) No census data
5	0.25	No	0.8	May 30, AM	0	0	2 dead magnolia warblers (*Dendroica magnolia*), 1 least flycatcher (*Empidonax minimus*), 3 sick warblers
6	0.25	Yes	0.8	June 5, PM	4	2	No apparent effect
7	0.25	No	0.2	June 6, PM	*	*	No apparent effect
8	0.25	Yes	0.4	June 6, AM	5	2	Slight population depression, sick Tennessee warbler (*Vermivora perigrina*)
9	0.25	No	0.8	June 6, AM	*	*	Sick and dead birds found in area covered by double application (0.5 lb. in 1.6 USG/acre)
10	0.25	Yes	0.8		*	*	No observations
11	0.25	Yes	0.8	June 12, AM	6	2	1 dead bay-breasted warbler (*Dendroica castanea*), 2 white-throated sparrows, 1 Swainson's thrush (*Hylocichla ustulata*); other species reduced in number
12	0.5	Yes	0.8	June 15, PM	3	4	Considerable mortality
13	0.5+	Yes	0.4?	June 15, PM	6	5	High mortality
14	0.25+	Yes	0.4?	June 16, AM	6	5	High mortality
15	0.25	Yes	0.2	June 20, AM	*	*	No observations
16	0.25	Yes	0.8	May 22, PM June 9, AM	5 4	6 2	Little effect
17	0.25	Yes	0.2	May 30, AM	*	*	No apparent effect
18	0.5 (0.25 x 2)	No	0.8 twice	June 7, AM twice	5	7	Considerable mortality (0.5 lb. in 1.6. USG)
Control				May 5 July 22	23	No spray	Tables 2, 3

*No census

Four additional plots, set up in 1968, provided further data on large-scale applications (Fig. 1).

Data on the effects of ultra-low-volume applications of technical phosphamidon were available in 1965, 1966 and 1968 from experiments conducted near Chipman, Blackville and Doaktown by the Chemical Control Research Institute, Department of the Environment.

Methods

The effects of spraying on birds were assessed by obtaining indices to changes in population before and after spraying according to the method used in 1964 (Fowle, 1965); by carefully searching sample areas for evidence of dead or disabled birds; and by experimenting with caged birds.

Population indices were obtained by establishing a census route near the centre of each sample plot. The routes, averaging 1.6 miles (2.6 km) in length, often ran along abandoned logging roads but most had sections running through unbroken forest. To select routes in comparable forest types we inspected the terrain from the air, on the ground and from aerial photographs. We marked routes with paint or coloured plastic ribbons fastened to the vegetation.

All censuses were taken between 5:30 and 10:30 AM but most were begun between 6:30 and 7:00 AM and were completed in 1 to 2 hours. The observer walked slowly along the route, recording the number of separate birds seen or heard. At the same time he tallied the total number of songs on a hand counter. It was, of course, nearly impossible to count discrete songs in such species as rose-breasted grosbeaks (*Pheucticus ludovicianus*) and red-eyed vireos (*Vireo olivaceous*) but experience showed that different observers obtained generally comparable indices.

Each census recorded time spent on the route and estimated the numbers of individual birds, songs and species. From these figures, indices of birds per minute and songs per minute were calculated. Information on weather and other factors influencing the census was also recorded.

The census technique was based on the hypothesis that changes in numbers of birds and possibly in species composition and frequency of songs and birds, would indicate changes in numbers or in activity of birds caused by spraying. These changes would be detected by comparing pre- and post-spray figures, by comparing simultaneous censuses of unsprayed and sprayed routes, and by following trends on control routes.

Table 2
Population indices on control plot, 1965

Date	Birds seen & heard	Birds min	Songs min	Species
May 5	84	0.8	3.3	20
May 7	129	1.3	3.8	20
May 8	118	1.2	4.4	22
May 10	129	1.5	7.6	20
May 11	130	1.5	5.3	22
May 12	149	1.5	5.7	27
May 13	151	1.5	7.1	30
May 17	173	1.6	7.4	32
May 20	160	1.4	9.1	23
May 23	179	1.8	6.3	28
May 28	181	1.6	3.8	30
May 31	227	2.1	17.2	40
June 2	211	1.9	8.7	36
June 9	224	1.7	13.5	28
June 10	242	2.3	15.3	37
June 13	173	1.7	9.4	31
June 17	178	1.8	15.1	34
June 24	164	1.8	15.4	28
June 28	164	1.9	15.0	31
July 3	129	1.5	7.4	27
July 9	160	1.6	10.1	30
July 15	144	1.5	6.5	35
July 22	144	1.5	4.2	30

Analysis of 1965 and 1966 data from control routes illustrates some factors that must be taken into account when results on the treated routes are interpreted. For example, the continuous arrival of migrants before the beginning of June may obscure the effects of spraying on plots treated in May. This is illustrated in Tables 2 and 3 in which an increase in species diversity is particularly striking.

Weather may cause some variations in results, but this has been difficult to demonstrate. The data in Tables 2 and 3 show that extreme weather conditions have an effect. On May 7, 1966, for example, frequency of song fell to 0.1 per minute and frequency of birds fell to 0.5 per minute. Overnight snowfall was about 1.5 inches, wind speed was 10–20 mph, temperature was 29°F, and the sky was overcast. On May 10, light sleet and cool temperatures probably

Table 3
Population indices on control plot, 1966

Date	Birds seen & heard	Birds min	Songs min	Species
May 5	56	1.2	7.3	10
May 6	92	1.7	5.9	11
May 7	19	0.5	0.1	7
May 8	63	1.2	4.5	12
May 9	105	2.1	10.9	15
May 10	38	0.8	1.6	8
May 11	42	1.0	1.3	6
May 13	93	1.9	7.1	14
May 14	84	1.8	6.2	16
May 16	78	1.8	8.2	12
May 25	138	2.5	15.9	28
May 27	119	2.3	16.4	28
May 28	121	2.4	14.8	26
May 29	155	2.9	18.0	31
May 31	132	2.6	12.6	30
June 10	103	2.3	15.6	28
June 12	120	2.0	14.7	28
June 14	116	2.4	15.1	29
June 16	84	2.1	13.9	28
June 18	99	2.6	14.9	25
June 19	84	1.9	12.4	25
June 20	89	2.2	12.5	28
June 21	81	2.0	10.8	27

resulted in the low figures recorded. But apart from these examples, I have not been able to ascribe clearly any fluctuations to weather factors. The data were too limited to determine how 30 to 40 species of birds with varying habits respond to fluctuations in weather.

Problems also arise in interpreting the figures for frequency of birds and song. In 1964 and 1968, when dosages of phosphamidon were sufficient to cause marked changes in numbers, these indices were useful in supporting other evidence of changes (Fowle, 1965). But in other years, when dosage was lighter and more subtle effects might be expected, interpretation was more difficult. Day-to-day variation made daily comparison with the control plot almost essential if changes in sprayed areas were to be discovered.

The relationship between numbers of songs and numbers of birds is not clear. Observations generally show a positive correlation between birds per minute and songs per minute, but variation is still considerable. Two or three birds singing persistently may increase the total songs on one census but not on another. Vireos, rose-breasted grosbeaks, purple finches (*Carpodacus purpureus*) and Tennessee warblers were sometimes in this category. Moreover, where some resident singing males are killed, disrupting territorial behaviour, the frequency of singing may change in the remaining or immigrant male replacements. Song frequency might be temporarily increased in establishing new territorial boundaries. But in spite of these difficulties, the indices of birds per minute and songs per minute were useful supports of other evidence of population changes, such as striking reductions in total birds seen and heard or the discovery of dead or sick birds.

It must be emphasized that this method was devised to detect changes in populations and not to measure absolute abundance. Variations in habits, frequency and volume of song and conspicuousness make such measurement impossible by this method (Colquhoun, 1940a, b).

In most cases spray was applied from Grumman Avenger (TBM) aircraft according to the procedure outlined by Flieger (1964); and by a modification of it, in 1968, in which formations of three aircraft instead of two were used.

From 1964 to 1967, spray was applied in what was called a "coarse" calibration achieved with the following specifications of equipment and flying procedure.

Flying speed: 150–155 mph.
Theoretical swath width: 412 feet.
24 (20–28) No. 4664 diaphragm tee-jet nozzles stripped of screens, strainers and tips and operating at low pressure, 18 (14–23) psi.
The nozzles were oriented straight down and break-up was achieved by the shear of the slip-stream.

In 1968 a "fine" calibration designed to give a larger number of very small drops was used in some applications with the following equipment and procedure.

Flying speed: 156 mph.
Theoretical swath width: 440 feet.
24–26 No. 4664 diaphragm tee-jet nozzles equipped with flat fan tips No. 8010 and operating at a pressure of 52–59 psi.
A fine break-up was achieved by turning the flat fans 45° into the wind.

The low-volume application was made in 1965 from Stearman aircraft fitted with Mini-Spin nozzles, in 1966 from a Stearman fitted with two Turbair nozzles and in 1968 from a Grumman Ag-Cat aircraft, fitted with Micronair nozzles.

Results

Table 4
Population indices on Plot 18 (0.25 lb./acre in 0.8 USG—two applications) for a total 0.5 lb./acre in 1.6 USG, June 7, 1965

Date	Birds seen & heard	Birds min	Songs min	Species
May 24	152	1.7	4.7	35
May 26	202	1.6	8.8	37
May 29	215	2.0	9.8	37
June 1	222	2.1	14.4	33
June 3	167	1.4	3.6	33
June 7	Sprayed twice AM			
June 8	85	0.8	1.2	25
June 9	70	0.7	2.2	19
June 12	83	0.9	3.7	21
June 15	87	0.9	5.3	28
June 19	97	1.1	9.7	27
June 25	98	1.1	10.1	28
July 2	105	1.3	7.9	26

Table 5
Population indices on Plots 13 and 14 (0.5 lb./plus and 0.25 lb./acre in 0.4 USG), 1965

Date	Birds seen & heard	Birds min	Songs min	Species
May 24	183	1.9	7.3	32
May 28	190	1.6	15.4	41
June 1	235	2.6	13.4	36
June 3	165	1.8	4.2	29
June 7	237	2.7	12.3	36
June 12	202	2.1	10.5	39
June 15*	213	2.2	9.7	35
June 16*	167	1.8	7.7	35
June 17	90	1.0	4.8	26
June 23	106	1.6	9.4	25
June 30	202	2.0	11.7	35

*Sprayed June 15, PM and June 16, AM. One hundred and ten birds were picked up incapacitated or dead, June 16–19:
2 ruffed grouse (*Bonasa umbellus*)—juv.
3 blue jays (*Cyanocoetta crestata*)
1 winter wren (*Troglodytes troglodytes*)
28 robins
9 hermit thrushes (*Hylocichla guttata*)
11 Swainson's thrushes
1 ruby-crowned kinglet
9 Tennessee warblers
1 Nashville warbler (*Vermivora rufficapilla*)
1 magnolia warbler
2 myrtle warblers
1 blackburnian warbler (*Dendroica fusca*)
2 bay-breasted warblers
2 yellowthroats (*Geothlypis trichas*)
1 brown-headed cowbird (*Molothrus ater*)
9 evening grosbeaks (*Hesperiphona respertina*)
1 purple finch
5 slate-coloured juncos
21 white-throated sparrows

Effects of the amount of phosphamidon applied

The assessment of the effects of dosages and dilutions must be based on the amount released from the aircraft, for we know little or nothing of the amount reaching the forest. Dosages of 0.125 to 0.5 lb./acre, in dilutions ranging from 0.2 to 0.8 USG/acre, may give varied results because weather conditions, and other factors affecting deposition, cause variation in amounts of phosphamidon reaching the trees. During this study, data on actual deposition at ground level was very limited.

In 1965, phosphamidon was emitted at the following rates: 0.25 lb. in 0.2, 0.4 and 0.8 USG/acre in coarse calibration. Two plots were sprayed with a double application of 0.25 lb. in 0.8 USG/acre. A fortuitous experiment was possible on Plots 13 and 14 when an apparent miscalculation in formulation and calibration resulted in a very heavy application, probably in excess of 0.5 lb./acre (Table 1).

In 1968, four applications were monitored: 0.375 lb. in 0.2 USG/acre applied in coarse calibration, as in 1965; 0.375 lb., 0.25 lb. and 0.125 lb. in 0.2 USG/acre applied in fine calibration.

Table 1 briefly summarizes the results for 1965. All applications of 0.5 lb./acre produced varying degrees of population reduction in the censuses, regardless of dilution, and dead and sick birds were quite easily found. Plots treated with 0.25 lb. doses showed little population change, and dead and sick birds were rare (Tables 4, 5, 6 and 7).

Applications of 0.5 lb. in 0.8 USG/acre were made on Plot 12 in 1965, using the procedure of 1964 (Fowle, 1965). Reduction in birds and song frequency was large, as in 1964. We saw or captured 39 incapacitated birds—17 white-throated sparrows, 12 wood warblers, 9 thrushes and 1 slate-coloured junco—and found 2 dead white-throated sparrows.

Table 4 shows the effects of a double dose of 0.25 lb. in 0.8 USG/acre on Plot 18. Adverse weather conditions account for the relatively low figures for June 3 and resulted in similarly low counts on two other unsprayed plots censused on that day. When the plot was searched 9 hours after spraying on June 7, 14 incapacitated birds (10 wood warblers, 1 red-breasted nuthatch, 1 least flycatcher, 1 Swainson's thrush and 1 white-throated sparrow) were seen or captured and song frequency ranged between 0.2 and 2.8 songs per minute. Outside the plot, 23 songs per minute were recorded. On June 8, 26 hours after spraying, five birds (1 least flycatcher, 1 Swainson's thrush, 1 red-eyed vireo, 1 Tennessee warbler and 1 bay-breasted warbler) were easily captured by hand. Others in obvious difficulty (ovenbird, scarlet tanager (*Piranga olivacea*), slate-coloured junco, white-throated sparrow) escaped capture. On June 9, we saw a thrush, two purple finches and a sparrow, all showing signs of intoxication, and found a dead nuthatch.

The same treatment on a portion of Plot 9 gave similar but less striking results. Several sick warblers were captured there.

The spray history of Plots 13 and 14 (Tables 5 and 6) is complicated by errors in formulation and by spraying of part of the census route in the evening of June 15 and the rest on the next morning. More than 0.5 lb./acre was apparently applied in the evening and 0.25 lb./acre was applied in the morning, but considerable drifting and some overlapping were reported. During the following 2 days, birds identified, frequency of song and number of species were considerably reduced. We picked up 110 dead and incapacitated birds in a fairly intensive search.

Applications of 0.25 lb./acre were apparently not detrimental to birds and where changes were observed they were minor compared with plots sprayed with 0.5 lb./acre. Ruby-crowned kinglets and myrtle warblers seemed more sensitive than other species (Table 7). We noted a reduction in singing in some cases, and occasionally found a few incapacitated or dead birds. Part of Plot 1 received a heavier dose of phosphamidon than was intended, when one aircraft lost a nozzle, and the overdose may have caused the mortality there.

The 1965 results suggested that birds were endangered when more than 0.25 lb./acre was applied in the coarse calibration. This conclusion was further supported by a search made on June 11, 1968, 8 hours after a coarse application of 0.375 lb. in 0.2 USG/acre on Plot 2. Song frequency was then extremely low, we captured three birds and saw sick Tennessee and myrtle warblers, a purple finch, chipping sparrow (*Spizella albicollis*) and white-throated sparrow.

But our 1968 experiments with fine calibration suggested an additional unknown factor apparently related to the calibration. On June 27, 0.25 lb. in 0.2 USG/acre were applied in a fine calibration on Plot 45. We noted no effect about 12 hours after spraying, but easily captured 6 wood warblers, 2 thrushes, a pine siskin

Table 6
Changes in numbers of individuals of selected species on Plots 13 and 14 sprayed PM June 15 and AM June 16, 1965

	Census on										
	May		June								
Species	24	28	1	3	7	12	15	16	17	23	30
Least flycatcher	6	3	7	1	7	2	2	1	0	1	5
Eastern wood peewee (*Contopus virens*)	0	0	1	1	1	2	3	2	0	0	5
Winter wren	7	10	9	8	8	6	5	1	0	2	3
Robin	11	10	8	9	9	4	5	4	1	3	8
Hermit thrush	0	2	0	2	2	3	2	3	1	1	2
Swainson's thrush	4	4	5	8	5	12	10	8	3	4	14
Ruby-crowned kinglet	5	3	5	8	9	4	5	4	0	2	3
Tennessee warbler	10	12	55	17	56	40	38	18	13	23	25
Magnolia warbler	11	7	4	1	10	6	7	6	5	6	10
Cape May warbler (*Dendroica tigrina*)	1	0	3	1	3	4	3	4	1	1	0
Black-throated blue warbler (*Dendroica caerulescens*)	4	3	7	4	2	3	2	2	2	2	1
Myrtle warbler	3	3	0	0	1	4	3	3	0	1	0
Black-throated green warbler (*Dendroica virens*)	6	4	4	4	4	6	1	1	0	0	3
Bay-breasted warbler	8	3	8	3	2	4	8	6	5	4	10
Ovenbird (*Seiurus aurocapillus*)	17	15	25	14	16	18	17	22	10	13	14
Yellowthroat	1	2	5	3	3	2	0	2	0	0	0
Common grackle (*Quiscalus quiscala*)	1	0	2	2	0	2	4	2	0	0	5
Brown-headed cowbird	6	10	1	4	2	9	2	2	1	1	4
Purple finch	15	8	8	8	13	*	14	14	8	9	19
Slate-coloured junco	7	3	2	8	3	6	5	5	5	5	5
White-throated sparrow	19	33	34	19	29	29	26	15	4	7	10

* Not recorded, finches undoubtedly present.

Table 7
Changes in numbers of ruby-crowned kinglets, Tennessee and myrtle warblers on Plots 1, 2, 8, 11 and control after spraying, 1965

Plot	Spray date and formulation	Species	Census date and results											
			May											
			5	6	10	12	13	14	15	17	19	22		
1	May 16, AM 0.25 lb. in 0.2 USG	R-c kinglet	10	15	17	15	17	11	16	2	1	0		
		T. warbler	0	0	0	0	3	0	1	3	0	21		
		M. warbler	0	2	13	9	20	15	19	4	2	0		
			May											
			5	6	7	9	12	13	15	16	17	19	21	24
2	May 16, PM 0.25 lb. in 0.8 USG	R-c kinglet	11	24	25	36	25	22	25	23	0	0	0	0
		T. warbler	0	0	0	0	0	0	0	0	3	0	0	0
		M. warbler	0	0	3	7	6	11	5	20	2	0	0	1
			May			June								
			22	26	29	1	3	7	10					
8	June 6, AM 0.25 lb. in 0.4 USG	R-c kinglet	6	10	8	6	5	0	4					
		T. warbler	16	11	11	43	34	12	16					
		M. warbler	7	3	8	2	8	1	2					
			May											
			24	28	29	1	3	9	13	15				
11	June 12, AM 0.25 lb. in 0.8 USG	R-c kinglet	16	17	14	14	13	22	1	3				
		T. warbler	12	5	49	69	31	51	20	33				
		M. warbler	7	4	8	4	2	2	3	0				
			May											
			5	7	8	10	11	12	13	17	20	23	28	31
Control	Not sprayed	R-c kinglet	8	6	14	20	12	16	12	11	12	11	12	12
		T. warbler	0	0	0	0	0	0	0	2	0	9	6	52
		M. warbler	2	4	8	9	9	10	13	11	9	3	3	4

Table 8
Population indices on Plot 25 (0.375 lb./acre in 0.5 USG, fine calibration), 1968

Date	Birds seen & heard	Birds min	Songs min	Species
May 22	231	2.0	10.2	35
May 24	364	2.8	12.7	44
May 25	284	2.4	10.9	39
May 27	312	2.6	10.6	36
May 31	310	2.6	12.8	31
June 3*	203	2.0	7.7	26
June 5	287	2.5	11.6	33
June 7†	Sprayed AM			
June 8‡	81	0.8	2.1	19
June 9‡	73	0.8	1.8	24
June 13	81	1.0	5.2	28
June 19	150	1.7	7.0	25
June 24	128	1.6	6.2	27
June 27	166	1.8	7.5	27
July 2	133	1.8	8.4	25

*Rain overnight, light continuous rain during census.
†Birds captured: 1 yellow-bellied sapsucker (*Sphyrapicus varius*), 1 robin, 1 Swainson's thrush, 2 Tennessee warblers, 2 Cape May warblers, 1 myrtle warbler, 1 Blackburnian warbler, 2 bay-breasted warblers, 1 American redstart (*Setophaga ruticilla*) and 2 chipping sparrows.
‡Birds captured: 1 flycatcher (*Empidonax* sp.), 1 robin, 1 hermit thrush, 2 Swainson's thrushes, 1 Tennessee warbler, 1 myrtle warbler, 1 bay-breasted warbler, 2 evening grosbeaks and 1 white-throated sparrow.

(*Spinus pinus*) and a white-throated sparrow and saw several more sick birds 24 hours after spraying. We would not have predicted such a great effect from the 1965 results. On June 7, 0.375 lb. in 0.2 USG/acre applied in a fine calibration on Plot 25 resulted in considerable mortality. Table 8 shows a striking depression in frequency of song, birds and species, counts similar to those recorded in 1965 when 0.5 lb. was applied in coarse calibration. We easily captured 25 birds and saw 25 sick birds (1 sparrow hawk (*Falco sparverius*), 1 yellow-bellied sapsucker, 6 flycatchers, 14 thrushes, 17 wood warblers, 3 evening grosbeaks, 2 chipping sparrows, 3 slate-coloured juncos, 3 white-throated sparrows) in about 13 man-hours of searching. The frequency of birds seen and heard on the census route was lower than on the control routes for the entire census period of 25 days following the date of spraying. On the evening of June 16, 0.125 lb. in 0.2 USG/acre were applied in fine calibration on Plot 32. A search 24 hours later revealed 2 wood warblers and 1 white-throated sparrow, all apparently sick. These observations were quite inconsistent with the results of previous experiments using coarse calibrations.

The 1968 data suggest that the type of calibration may be as important as the dosage but unfortunately we have no data on the actual range of droplet sizes dispersed by the two methods. Fine calibration may spread the insecticide more evenly over the foliage and twigs, increasing the frequency of its contact with the birds' feet. It may also produce more aerosol droplets, which the birds might inhale.

Effects of dilution

In 1965 phosphamidon was applied in aqueous dilutions of 0.2, 0.4 and 0.8 USG/acre of formulation. Changes in bird population were not directly related to dilution.

Low volume concentrate applications

The study of the effects of low volume applications was carried out in co-operation with A. P. Randall, Chemical Control Research Institute, who conducted four experiments in 1965, 1966 and 1968. He applied 90 per cent technical phosphamidon by aircraft fitted with equipment capable of

Table 9
Census near Chipman after low volume concentrate application (0.25 lb./acre) June 12, 1965

Date	Birds seen & heard	Birds min	Songs min	Species
Experimental plot				
June 14	42+	0.7	2.2	19
June 15	46+	1.2	9.1	22
Control				
June 14	52+	0.9	5.5	10
June 15	90+	2.1	15.6	26

Table 10
Population indices near Blackville before and after low volume concentrate application (0.4 lb./acre), 1966

Date	Birds seen & heard	Birds min	Songs min	Species
May 17	91	1.4	7.4	25
May 19	70	1.4	6.7	21
May 22	121	2.2	15.6	35
May 24	109	2.0	14.9	32
May 25	133	2.2	21.4	34
May 27	Sprayed AM			
May 28	55	1.1	6.8	24
June 1	61	1.2	14.5	27
June 20	74	1.6	13.4	29

Table 11
Changes in numbers of individuals of selected species on a plot near Blackville sprayed with low volume concentrate AM May 27, 1966

	Numbers on								
	May							June	
Species	17	19	22	24	25	27*	28	1	20
Yellow-shafted flicker (*Colaptes auratus*)	2	1	2	1	0		0	1	0
Yellow-bellied sapsucker	12	10	8	10	10		5	5	3
Blue jay	2	2	3	2	3		1	0	1
Boreal chickadee (*Parus hudsonicus*)	1	2	1	1	2		0	0	0
Robin	2	4	3	1	2		2	1	1
Hermit thrush	3	2	4	3	4		3	1	2
Ruby-crowned kinglet	11	8	9	6	5		2	1	2
Tennessee warbler	0	0	5	16	22		8	13	14
Nashville warbler	0	0	1	2	2		0	1	3
Parula warbler (*Parula americana*)	0	0	3	1	1		0	1	0
Magnolia warbler	0	0	3	3	5		1	5	3
Cape May Warbler	2	3	5	3	5		0	1	2
Myrtle warbler	9	8	9	7	6		1	3	2
Black-throated green warbler	0	0	2	2	1		0	0	0
Blackburnian warbler	0	0	1	0	2		0	2	1
Bay-breasted warbler	0	0	1	1	4		0	1	2
Ovenbird	1	2	11	11	13		2	4	6
Yellowthroat	0	0	2	2	2		1	2	2
Brown-headed cowbird	3	1	3	1	2		0	1	1
Purple finch	5	7	6	6	4		1	2	3
Slate-coloured junco	8	0	7	1	4		0	4	2
White-throated sparrow	14	11	16	11	12		8	2	4
Total	75	61	105	91	111		35	51	54

* Sprayed

emitting the compound at low volumes per acre in dosages equivalent to those of active compound applied in our experiments.

In 1965 two 400-acre plots were used near Chipman. The first was treated with 10 USG (equivalent of .25 lb./acre) and the second with 20 USG (equivalent of .5 lb./acre). The wetting agent was Invadine JFC.

The plots were sprayed by a Stearman aircraft with Mini-Spin nozzles. The insecticide was applied in a graduated dosage across the plot by varying the swath width. Thus dosage on one side of the plot was higher than on the other, with intermediate dosages between. The spray deposit was measured by droplet counts collected on cards and by colorimetric analysis of the deposit landing on glass slides placed at intervals across the plot.

The plot receiving 0.25 lb./acre was censused. Pre-spray censuses were not taken, but post-spray censuses, comparison with an unsprayed area and searches for affected birds provided some information (Table 9). The plot was sprayed on June 12, between 7 and 7:30 AM and searched between 2 and 3 PM. No dead or sick birds were found and 10 species were seen or heard on the plot. The song frequency was 2.1 per minute for eight species, but 12.6 per minute for nine species on an unsprayed area about 1 mile away. Heavy rain on June 13 prevented immediate follow-up, but counts were made on June 14 and 15 on the plot and on a nearby control. The weather on June 14 was unfavourable for a good census, but better on June 15. The lower frequency of songs and birds per minute on the experimental plot indicates population depression, but as spraying was uneven we could not say what dosage affected the birds. No dead or sick birds were found.

The second plot treated with 0.5 lb./acre was not censused. However, Randall reported the discovery of three sick birds (1 ruffed grouse chick, 1 Tennessee warbler and 1 magnolia warbler). These observations are consistent with those of other plots sprayed with 0.5 lb./acre or more.

In 1966, a low volume concentrate application of 0.4 lb./acre, using Turbair

Table 12
Songs per minute at six listening stations on two transects across a plot near Blackville, before and after low volume concentrate application of technical phosphamidon May 27, 1966

Station	Est. deposit in lb./acre after spraying on May 27, AM	Songs/minute on May 17	1	22	24	25	28	June 1	20
Transect A									
1		14.3	12.0	25.7	24.3	36.3	12.0	17.0	
2	0.20	20.3	8.7	25.3	28.0	31.0	7.7	5.7	25.7
3	0.34	10.0	8.3	19.3	22.7	37.3	5.3	10.0	27.0
4	0.14	9.0	3.3	21.0	29.7	35.3	4.0	5.3	23.3
5	0.38		1.3	21.7	17.0	34.3	15.7	7.3	19.3
6			9.7	26.3	27.3	37.0	24.0	15.3	18.3
Transect B									
1		8.0	4.3	20.0	25.0	31.3	11.0	10.7	
2	0.22	20.3	6.3	15.0	17.7	32.0	5.0	8.7	21.0
3	0.20	10.0	3.7	23.0	23.0	30.7	7.7	2.7	8.0
4	0.22	9.0	1.7	23.0	22.3	32.7	5.7	8.3	20.3
5	0.30		5.3	7.0	21.7	32.3	15.0	13.2	24.3
6			10.3	21.3	23.3	31.3	20.0	14.3	26.3

nozzles, was made near Blackville on the morning of May 27. One sick Tennessee warbler and 1 white-throated sparrow were found about 4 hours after spraying, and 1 sick magnolia warbler, 2 ovenbirds and 1 white-throated sparrow in the afternoon after a search of 7 man-hours. Several sick birds (Swainson's thrush, hermit thrush, magnolia warbler, Cape May warbler, slate-coloured junco and 2 white-throated sparrows) were seen on the morning of May 28. A dead white-throated sparrow was found on June 1. Tables 10 and 11 indicate some reduction in population.

To relate population reduction to application rate, two transects of six listening stations each were established across the plot at right angles to the spray swaths. Stations 1 and 6 on each line were outside the plot, the remaining four were at 8-chain intervals so the varying dosages across the plot could be sampled. Indices to bird activity were obtained by counting species seen and songs heard at each station during 3-minute periods. Table 12 shows that the greatest depression in song frequency occurred in the region of highest dosage, where 0.14 to 0.38 lb./acre had been deposited on glass slides set out to collect samples. The deposition rate at the sampling stations ranged from 0.10 to 1.05 lb./acre: more than 0.25 lb./acre at six stations, and more than 0.5 lb./acre at five.

Information collected in 1964 and 1965 suggested that avian mortality might occur when 0.5 lb./acre, or more, was released. At that time, no estimate of actual deposit was available. The 1966 experiment measures deposits and relates them to effects. The results suggest that a deposit is lethal even when considerably less than 0.5 lb./acre actually reaches vegetation.

On the evening of May 23, 1968, a third ultra-low-volume application of 0.25 lb./acre technical phosphamidon was made over a 400-acre block from a Grumman Ag-Cat, fitted with two AU 3000 Micronair nozzles. Flight lines were arranged to produce a graduated dose across the plot. The results were similar to those in 1966. Song was almost eliminated for at least 24 hours after spraying. Several sick birds were seen or captured. Song was still infrequent 90 hours after spraying. Few birds were seen.

Effects of spray early and late in the season

The original experiment design of 1965 called for an application in the first week of May, before most migrants had returned, which could be compared with results from applications later in June. Unfortunately, bad weather and the budworm's slow development made it impossible to spray before May 16, about 2 weeks earlier than the first application in 1964. In 1966, however, an application was made on May 5. In both cases the dose was 0.25 lb./acre.

Between May 5 and 16, 1965, we saw 38 species, of which six were warblers in very small numbers, on Plot 2 (Table 7). Ruby-crowned kinglets and magnolia warblers were noticeably reduced when compared with control routes. Before spraying on May 5, 1966, we observed 24 species, none of them warblers, on the same plot. We detected no population changes after spraying, other than a possible slight reduction in kinglets.

If early application satisfies the requirements for insect control, it would be preferable as it would reduce hazard to birds.

The effect of Invadine JFC

The wetting agent Invadine was included in the formulation on all but four plots, in 1965. This produced no effects assignable to Invadine.

The effect of two applications

Two plots were sprayed twice: Plot 16 was sprayed with 0.25 lb. in 0.2 USG/acre on May 22 and on June 9, 1965. Plot 3 was sprayed on May 5 and 13, 1966. Changes in numbers of birds were not apparent, possibly because only a few migrants had returned by these dates (Table 4).

Experiments with caged birds

Preliminary experiments in 1964 suggested that birds may be poisoned by dermal contact with sprayed foliage and twigs (Fowle, 1965). A series of experiments carried out from 1965 to 1968 demonstrated that birds can pick up a lethal dose of phosphamidon through their feet. Exposure to perches, twigs, foliage and plastic surfaces sprayed with various concentrations of phosphamidon produced symptoms of poisoning and, in many cases, death.

A number of factors frustrated our attempts to carry out entirely satisfactory experiments in the field. It is very difficult to perform systematic experiments, with controls that might be expected to yield reasonably consistent results, when working with freshly caught wild birds. In the first place it is virtually impossible to capture a substantial number of any one species, except for such species as white-throated sparrows and house sparrows (*Passer domesticus*). For example, netting warblers seems largely a matter of chance, especially in late summer. Moreover, such factors as age, sex, time in the net before release, duration and conditions of captivity before the experiment and time since the last feeding are likely to condition the birds' response. These complications limit experimentation, but we obtained useful though meagre information probably valuable because it applies to birds actually living in the forest where the insecticides are used. Our use of controls also had limitations because we could not get a sufficiently varied supply of specimens. We could more easily experiment with house sparrows in the laboratory as they were more readily available and easier to care for than most wild species.

In the first experiments we placed birds in cages containing perches cut from twigs and painted with various concentrations of phosphamidon. The results were not consistent for all species and individuals, as some birds spent most of their time moving about on the floor of the cage or sitting still for long periods on a perch or on the floor. But when birds used perches freely some effect was usually apparent.

Two cedar waxwings (*Bombycilla cedrorum*) were placed in separate cages. Perches

Table 13
Survival of birds with dermal doses of technical phosphamidon applied to the feet

Species	Dose, mg/kg	Hr to symptoms	Hr to death
Robin	200		No symptoms in 7 hr*
Swainson's thrush	100		Released after 10 hr
	400	4.0	8.0
	550		3.0
	600		5.0
Hermit thrush	400	2.0	4.0
	400		2.5
Veery (*Hylocichla fuscescens*)	200		Survived 10 hr*
Tennessee warbler	100		Released after 10 hr
Myrtle warbler	500	2.0	4.0
Blackburnian warbler	100		Released after 17 hr
Bay-breasted warbler	400		Released after 10 hr
Ovenbird	400	5.0	9.5
Northern waterthrush (*Seiurus noveboracensis*)	400		0.25
House sparrow	200	5.5, slight	6–22
	400	5.5, slight	5.5–8.5
	400	5.5	Helpless in 10 hr*
	400	3.5	6–10
	400	5.0	Nearly dead in 10 hr*
	400	5.0	Nearly dead in 10 hr*
	500		5.5–8.5
	600	8.5	10–21
	700	0.75	3.25
	700	3.5	Nearly dead in 11 hr*
	700	3.5	Nearly dead in 7 hr, died in 9.5
	700	0.16	Nearly dead in 7 hr*
	700	3.0	4.25
Evening grosbeak	100		22
	200		Released after 18 hr
	200		24–27
	300		3–4
	300		13–14
	300		11.5
	400	1	2.5
	400	3–5	5
	400		6–8
	400		27
	400		24
	400		13–21
	600		8–9
	600	4	6–10
Purple finch	200	1.5, slight	25–28
	300	3.5, slight	9.5–20.5
	400		.25–1.25

Table 13 cont'd.

Species	Dose, mg/kg	Hr to symptoms	Hr to death
Slate-coloured junco	400	2.5	7
	500	4.0	12
White-throated sparrow	200		9.5
	400	1.25	7.0
	400	4–5	7
	700	3	5
Song sparrow	200	2.5	7+

*Died in night, exact time cannot be given.

Table 14
Survival of birds with dermal doses of technical phosphamidon applied under the wing or on the breast

Species	Dose, mg/kg	Hr to death
Evening grosbeak, applied on breast	200	6.75
	200	4–6
	300	6.75
	300	3.75–6.75
Purple finch, applied under wing	50	7.5
	100	3.0
	200	.66
	200	2–3
	300	0.25–1.25
	400	1.5

in one were painted with a solution of phosphamidon equivalent to the 0.2 USG/acre dilution and in the other with solution equivalent to the 0.4 USG/acre dilution. The bird on the higher concentration was affected after about 5 hours: it became unsteady, unable to maintain its stance if disturbed, and passed a large number of viscous droppings. The other bird was less active on the perches, but showed a slight effect after 5 hours.

A white-throated sparrow using perches painted with technical phosphamidon was trembling 22 minutes after contact, passed viscous droppings and was dead in 29 minutes.

Three Traill's flycatchers (*Empidonax trailii*) were exposed to perches painted with 13, 7 and 3.8 per cent phosphamidon. The bird on 13 per cent concentration showed symptoms in 2 hours, was incapacitated and died 6.5 hours after exposure; the one on 7 per cent concentration began trembling in 3.7 hours and was dead in 5 hours; the one on 3 per cent concentration showed no symptoms after 6 hours, but it had been inactive and had not spent as much time on the perches as the other two.

Two Tennessee warblers died after exposure to 7 and 3.8 per cent solutions. The one on the low concentration began to tremble in 33 minutes, was incapacitated in 1.6 hours and died 2.5 hours after exposure. The other bird died in 3.5 hours.

Catbirds (*Dumetella carolinensis*), ovenbirds and song sparrows (*Melospiza melodia*) survived similar experiments without showing any ill effects, possibly because they did not use the perches a great deal or because of species and individual differences in reacting to phosphamidon.

In a second series of experiments song sparrows and a few other species were placed in cages floored with sheets of polyethylene smeared with varying amounts of phosphamidon. Results varied considerably, probably because the birds could not move about easily on the smooth surface and the soles of their feet were not in proper contact with it. However, an ovenbird, a Nashville warbler and several song sparrows showed symptoms soon after exposure and died later.

Additional experiments using a microsyringe to deposit carefully measured quantities of technical phosphamidon on the soles of birds' feet provided a rough quantitive measure of levels of dermal toxicity (Table 13). We could not determine how much of the chemical actually penetrated the skin and was carried by the blood through the body, for a large percentage may have remained on the skin or may have been wiped off. But the amount applied is directly related to the time until symptoms appeared, or death occurred. All the experiments clearly indicated that debilitating or lethal doses can be picked up through the feet.

By extrapolating these results to the situation in the field we can understand how birds might pick up a lethal dose. For example, a juvenile warbler died in 3.5 hours from a dose of 0.002 ml in volume (200 mg/kg). A bird moving over surfaces receiving 5 to 20 drops/cm^2 in a low volume application would soon pick up a dose of this size.

Evidence that birds are most likely affected through dermal contact is substantial, but other means of contamination were also examined. The results indicated that normal operational spraying could not put enough spray on the feathers of individual birds to poison them. Robins, Swainson's thrushes and magnolia warblers were lightly sprayed at close range, with a hand atomizer containing 3.8 or 7 per cent solutions, without apparent effect, even though the doses were probably heavier than those encountered in operational spraying. White-throated sparrows exposed in open areas to operational applications of 0.25 lb. in 0.8 USG/acre were apparently not affected. Traill's flycatcher, veery, magnolia warbler and song sparrow were given heavier doses on patches of feathers around the head or on the wings using cotton swabs soaked in solutions of various concentrations. The birds were wet and the feathers stuck together. Most of them developed the typical symptoms and died within a few hours.

Table 14 shows that doses applied to bare skin under the wing and on the breast induce symptoms, and may kill birds, more rapidly than equivalent doses applied to the feet.

Some birds may be affected by inhaling vapour or aerosol droplets, although there is little experimental evidence of this. In 1968, 4 purple finches and a white-throated sparrow were enclosed in separate cages, covered with polyethylene sheaths, each with an open but screened Petri dish containing 5 to 10 ml of technical phosphamidon from which vapour could be emitted. The birds showed no ill effects after exposure of up to 9 hours at temperatures ranging from 65° to nearly 90°F.

Thirteen species were given oral doses. Appropriate volumes of aqueous solution were measured with a microsyringe and placed in the end of a small-gauge plastic tube fastened to a hypodermic syringe. The tube was then placed in the upper end of the oesophagus and the chemical forced out. The results, tabulated in Table 15, suggest that 1 to 3 mg/kg is a lethal dose for most species.

Caged birds poisoned with phosphamidon displayed the following symptoms in varying combinations. First, they sat still for some time with feathers erect, eyes blinking or closed, their bills occasionally opening in an apparent attempt to regurgitate the dose. They often passed soft, watery droppings. They later began to tremble, tail vibrating and wings drooping, before slowly or suddenly sinking down onto their tarsi. They usually fell over, sometimes with legs outstretched and generally with toes curled. Some birds shook their heads, wiped their bills on the perch and occasionally succeeded in regurgitating some food and probably a good deal of the dose. The response probably varied as in the two cowbirds (Table 15), because some birds regurgitated soon after taking the dose.

Birds collected from the experimental plots showed similar symptoms. Seriously affected birds could not fly and were incapacitated in the same way as the caged birds. Others, apparently less affected, wiped their bills on twigs and branches. Frequent bill wiping might be evidence of a low level of intoxication when incapacitated birds are not found.

Table 15
Survival of birds given oral doses of phosphamidon in aqueous solution

Species	Dose, mg/kg	Dilution	Min to symptoms*	Min to death*
Traill's flycatcher	5	1/100		7
Catbird, adult	2	1/100	20	Recovered in 1 hr, freed in 2 hr
Catbird, juvenile	5	1/100		13
Robin	2	1/100		26
	5	1/100		9
Swainson's thrush	2	1/150	20	Freed in 13 hr
	2	1/150		20
	5	1/100	30	3.5 hr
	5	1/100	20	Recovered in 2.5 hr
	5	1/100	20	Recovered in 4 hr
	5	1/100	10	17
	5	1/150	20	Recovered, freed
	5	1/150	15	20
Veery	2	1/150	Slight	Recovered, freed
	2	1/150	3.75 hr	3.75 hr
Cedar waxwing	5	1/100		9
	10	1/100		10
Cowbird	5	1/20		10
	5	1/20	10	Survived 9 days, freed
Evening grosbeak	1	1/100	Slight	Unable fly after 20 hr
	1	1/100	Slight	Freed after 20 hr
	1	1/100	Slight	Freed after 20 hr
	2	1/100	10, lasted 3 hr	Recovered but unable fly after 20 hr
	2	1/100	15	41
	2	1/100	10	34
	2	1/100	14	26
	2	1/100	15	45
	5	1/100	10	15
	5	1/100	11	16
Purple finch	2	1/200	25, slight	Recovered, freed
	2	1/200	No effect?	
	2	1/200	55, slight	Unable fly after 13 hr
	2	1/200	50, slight	Freed after 13 hr
	3	1/100	15	30
	3	1/100	47	Unable fly after 20 hr
	3	1/100	14	32
	3	1/100	23	Could barely fly after 20 hr
	3	1/300	30	43
	3	1/300	Regurgitated	Freed after 20 hr
	3	1/300		22
	3	1/300	26	Freed after 19 hr
	3	1/600	40	Freed after 19 hr
	3	1/600	27	47
	3	1/600	13	Freed after 18 hr

Table 15 cont'd

Species	Dose, mg/kg	Dilution	Min to symptoms*	Min to death*
Purple finch	3	1/600	22	Unable fly after 20 hr
	5	1/200	14	45
	5	1/200	20, regurgitated	Died after 30 hr
	5	1/200	15	31
	5	1/200		1–2 hr
	8	1/200	7	11
	8	1/200	9	21
Pine grosbeak	2	1/100	18	28
Pine siskin	2	1/100	27	36
	2	1/200	17	3–11 hr
	2	1/200	23	3–11 hr
	2	1/300	34	Freed after 19 hr
	2	1/300	11, regurgitated	19 hr
	2	1/600	21	41
	2	1/600	25	17 hr
	5	1/200	21	23
	5	1/200		19
	8	1/200	5	27
	8	1/200	25	34
Red crossbill	2	1/100	13	37
	5	1/100	5	14
Song sparrow	2	1/200	13	Freed after 12 hr
	5	1/100	10	12
	5	1/100	7	19

* Unless other unit shown.

Discussion and conclusions

The study suggested these conclusions:
1. Operational aerial spraying of phosphamidon at emission rates of 0.375 to 0.5 lb./acre may result in substantial mortality of forest birds. Lower doses of about 0.25 lb./acre may occasionally cause losses. Sprays with a high proportion of fine evenly dispersed droplets may do more damage than those with fewer fine droplets.
2. Birds can pick up lethal or debilitating doses from sprayed vegetation through their feet.
3. Birds may be poisoned by eating sprayed food soon after spraying. Doses of 1 to 3 mg/kg of active ingredient are sufficient to kill common forest birds.

These findings are consistent with earlier reports from New Brunswick (Fowle, 1965). The earliest evidence that phosphamidon might be dangerous to birds was obtained in Switzerland in 1963 (Schefferli, 1966), when 0.89 lb./acre applied to a larch forest resulted in considerable reduction of a diverse avifauna. Finley (1965) reported on the effects of applying 1 lb./acre in a spruce budworm control program in Montana in 1963. Although the bird population in that experimental area was not as great or as diverse as in New Brunswick, the reduction in number was striking. It is of particular interest that several blue grouse (*Dendragapus obscurus*) had symptoms of organophosphorous poisoning. These birds have a largely vegetarian diet (Fowle, 1960; Stewart, 1944) and Finley suggests they may have been poisoned by their food or by dying budworm in their food. In 1964, phosphamidon was used on the Queen Charlotte Islands, British Columbia, in a control program for green-striped forest looper (*Melanolophia imitata*) (Kinghorn and Richmond, 1965). The application was made from a helicopter at the rate of 0.8 lb. per USG/acre. McCaughran (1964) reported a very substantial reduction in birds on sample areas and the discovery of dead and sick birds in treated areas. McLeod (1967) reported mortality, mainly of warblers, after 0.25 lb./acre was applied to a jack pine forest in eastern Quebec.

In contrast, McEwan and Tucker (1965) reported no effect on a high density of nesting mourning doves (*Zenaidura macroura*) after 3.08 lb./acre were applied to a lemon orchard near Yuma, Arizona, in July 1965. A speed-sprayer towed by tractor applied about 135 gal/acre in a very dilute solution of about 0.2 per cent active ingredient. Doves were observed on nests 4 hours after spraying, and nesting success on the experimental area compared favourably with the control. It is difficult to interpret these results in the light of findings in New Brunswick and elsewhere. The difference probably lies in the much greater spray dilution and the habits of the doves. These birds do not move about through the foliage or hop from perch to perch. They are primarily ground feeders and probably feed outside the orchards. They tend to fly directly to the nest or a nearby perch without moving about very much. Brooding birds may have protected the eggs and chicks by staying on the nest during spraying. But even if they did not, the foliage may have sheltered the chicks in nest sites preventing all but a small amount of very dilute insecticide from reaching them. Laboratory tests showed that the doves were as sensitive to phosphamidon as other species, so their survival in this experiment was probably related to behaviour or to the dilution (Agrochemical Division, 1967; McEwan and Tucker, 1965; Tucker and Crabtree, 1970).

Experiments with captive birds confirmed reports of the high oral toxicity of technical phosphamidon (George, 1963). Dettrich (1966) and Schifferli (1966) report oral toxicity in the order of 4 mg/kg and temporary incapacity at 2 mg/kg in house sparrows. Higher doses of about 20 mg/kg have been reported for chickens (*Gallus gallus*) (Agrochemical Division, 1967). Bull, Lindquist and Grable (1967) point out that technical phosphamidon usually contains about 30 per cent of the essentially non-toxic *cis* isomer. Experiments in this study show that the toxic level for many forest birds runs between 1 and 3 mg/kg of technical phosphamidon.

Literature cited

Agrochemical Division. 1967. Dimecron. CIBA Ltd. Basle. Switzerland. 257 p.

Bull, D. L., D. A. Lindquist and R. R. Grable. 1967. Comparative fate of the geometric isomers of phosphamidon in plants and animals. J. Econ. Ent. 60(2): 332–341.

Colquhoun, M. K. 1940a. The density of woodland birds determined by the sample count method. J. Anim. Ecol. 9:53–67.

Colquhoun, M. K. 1940b. Visual and auditory conspicuousness in a woodland bird community; a quantitative analysis. Proc. Zool. Soc. London 110:129–148.

Dettrich, V. 1966. Investigations on the acute oral toxicity of different pesticides on nestlings of *Parus ater* and adults of *Passer domesticus*. Z. F. Angew. Ent. 57(4):430–437.

Finley, R. B. 1965. Adverse effects on birds of phosphamidon applied to a Montana forest. J. Wildl. Mgt. 29(3):580–591.

Flieger, B. W. 1964. A new method for guiding spray aircraft. Can. Dep. For. Bi-Monthly Rep. 20(1):2–4.

Fowle, C. D. 1960. A study of the blue grouse (*Dendragapus obscurus* (Say)) on Vancouver Island, British Columbia. Can. J. Zool. 38:701–713.

Fowle, C. D. 1965. A preliminary report on the effects of phosphamidon on bird populations in central New Brunswick. Can. Wildl. Serv. Occas. Pap. No. 7. 54 p.

George, J. L. 1963. Recommendations for minimizing effects of pest control and pesticides to fish and wildlife. *In* Pesticide – Wildlife Studies. U.S. Dep. Int. Fish & Wildl. Serv. Cir. 167:101–105.

Kinghorn, J. M. and H. A. Richmond. 1965. The green-striped forest looper infestation, Queen Charlotte Islands. Part II Experimental control with phosphamidon. Can. Dep. For., For. Res. Lab. Info. Rpt. BC-X-1.

Loucks, O. L. 1960. A forest classification for the Maritime Provinces. Proc. N.S. Inst. Sci. 25 (Pt.2) 1959–60:85–167.

McCaughran, D. A. 1964. Summary of wildlife mortality assessment caused by spraying green-striped forest looper on the Queen Charlotte Islands with phosphamidon. B.C. Dep. Conserv. & Recr. Fish & Game Branch. Victoria. Mimeo. Quoted by permission.

McEwan, L. and R. Tucker. 1965. Observations on effects of phosphamidon on nesting doves at Yuma, Arizona. Unpublished report. U.S. Dep. Int. Denver Wildl. Res. Centre. Denver. Quoted by permission.

McLeod, J. M. 1967. The effect of phosphamidon on bird populations in jack pine stands in Quebec. Can. Field-Nat. 8(2):102–106.

Morris, R. F., W. F. Cheshire, C. A. Miller and D. G. Mott. 1958. The numerical response of avian and mammalian predators during a gradation of the spruce budworm. Ecology 39(3):487–494.

Rowe, J. S. 1959. Forest regions of Canada. Can. Dep. Northern Affairs and Nat. Resources. For. Br. Bull. 123. 71 p.

Schifferli, A. 1966. Auswirkungen einer Inseck-tizid – Aktion gegen den Grauen Lärchenwickler auf die Vogelwelt im Goms (Oberwallis). Der Ornith. Beob. Bd. 63(2):25–40.

Squires, W. A. 1952. The birds of New Brunswick. N.B. Mus. Monog. Ser. No. 4. Saint John. 164 p.

Stewart, R. E. 1944. Food habits of the blue grouse. Condor. 46:112–120.

Tucker, R. K. and D. G. Crabtree. 1970. Handbook of toxicity of pesticides to wildlife. U.S. Dep. Int. Fish & Wildl. Serv. Resource Publ. 84:1–131.

Wilson, W. G. 1968. Habitat selection of forest birds in Central New Brunswick. M.Sc. Thesis, York Univ. Toronto. 150 p.

Other publications in the Report Series

No. 1
Whooping crane population dynamics on the nesting grounds, Wood Buffalo National Park, Northwest Territories, Canada by N. S. Novakowski
Cat. No. R65-8/1, Price 50 cents

No. 2
Bionomics of the sandhill crane by W. J. Stephen
Cat. No. R65-8/2, Price 75 cents

No. 3
The breeding biology of Ross' goose in the Perry River region, Northwest Territories by John Pemberton Ryder
Cat. No. R65-8/3, Price 75 cents

No. 4
Behaviour and the regulation of numbers in blue grouse by J. F. Bendell and P. W. Elliot
Cat. No. R65-8/4, Price $1.00

No. 5
Denning habits of the polar bear (*Ursus maritimus* Phipps) by Richard Harington
Cat. No. R65-8/5, Price 50 cents

No. 6
Saskatoon Wetlands Seminar
Cat. No. R65-8/6, Price $5.25

No. 7
Histoire naturelle du Gode, *Alca torda*, L., dans le golfe Saint-Laurent, province de Québec, Canada, par Jean Bédard
Cat. No. R65-8/7, Price $1.25

No. 8
The dynamics of Canadian arctic fox populations by A. H. Macpherson
Cat. No. R65-8/8, Price $1.00

No. 9
Population estimates of barren-ground caribou, March to May, 1967 by Donald C. Thomas
Cat. No. R65-8/9, Price $1.00

No. 10
The mammals of Jasper National Park, Alberta by J. Dewey Soper
Cat. No. R65-8/10, Price $2.50

No. 11
A study of sex differential in the survival of wapiti by Donald R. Flook
Cat. No. R65-8/11, Price $1.25

No. 12
Breeding biology of California and ring-billed gulls: a study of ecological adaptation to the inland habitat by Kees Vermeer
Cat. No. R65-8/12, Price $1.25

No. 13
Geographical variation in the polar bear, *Ursus maritimus* Phipps by T. H. Manning
Cat. No. R65-8/13, Price $1.00

No. 14
Studies of bird hazards to aircraft
Cat. No. R65-8/14, Price $1.25

No. 15
Moose and deer behaviour in snow by J. P. Kelsall and W. H. Prescott
Cat. No. R65-8/15, Price $1.00