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Impact on forest birds of the 1976 spruce budworm spray operation in New Brunswick

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Abstract

The impact on breeding birds of a highly complex, 3.9 million-ha forest spray operation against spruce budworm in New Brunswick in 1976 was assessed by surveys of singing males along walked transects totalling 135 km. Effects were variable; a given spray regime would cause mortality and demonstrable changes in the numbers of singing birds in some cases, but not in others. Bird migration concurrent with early stages of the spray operation may have masked the impact on some species. In general, exposed canopy feeders were the most vulnerable.

Phosphamidon, used only on about 139 000 ha, was very toxic to birds when sprayed by TBM aircraft, but much less so when delivered by C-46 aircraft. The effect of fenitrothion, used on approximately 3.5 million ha, appeared to be significantly greater when sprayed by TBM than when applied at the same dosage, but in a different formulation, by DC-6 aircraft. Aminocarb was monitored only in spray regimes including prior use of either phosphamidon or fenitrothion, but appeared to have little additional impact on birds. Using the Ruby-crowned Kinglet, a canopy feeder, as a key indicator species, we calculated that the 1976 spray operation caused only one-quarter as many bird casualties as did the 1975 spray program in New Brunswick, although spraying covered 40% more territory in 1976. We attribute the markedly reduced impact on birds largely to the near elimination of phosphamidon as an operational larvicide, and possibly to the DC-6 spraying in about one-fifth of the total area treated.

Results of roadside surveys of breeding birds conducted on standard routes during the 10-year fenitrothion spray era in New Brunswick indicate no long-term depression of bird numbers, suggesting that the natural resilience of bird populations has compensated for the sometimes substantial, short-term impacts that have been attributed to forest spraying.

Introduction

In a continuing attempt to protect the New Brunswick spruce–fir forest against severe defoliation and tree mortality caused by spruce budworm (*Choristoneura fumiferana*), an aerial spray program was again mounted in that province in 1976, the 24th such undertaking since 1952. By the late 1960s, DDT has been phased out and had been replaced by organophosphates. Since then, fenitrothion has been the insecticide of choice for spraying against budworm in New Brunswick, although in some years phosphamidon was used fairly extensively. Even at relatively low dosages, those organophosphate insecticides were shown to be hazardous to songbirds under certain operational conditions (Fowle 1965, 1972, National Research Council 1975, Pearce, Peakall, and Erskine 1976). Recently the carbamate insecticide aminocarb has been used in increasing amounts.

The 1976 spray operation in New Brunswick was the largest and the most complex on record in that province. A total of about 1.7 million kg (active ingredient) of four insecticides was released over nearly 3.9 million ha of forest. Much of the area was sprayed twice, and a relatively small area three times (Figure 1). There were 23 insecticide spray regimes, nine of which were used on tracts of forest of 50 000 ha or more (Table 1). The term "insecticide spray regime" means the sequence of treatments applied at prescribed dosages by specific aircraft.

Forest spray operations were monitored jointly by the Canadian Wildlife Service (CWS) and the Fish and Wildlife Branch and Forest Service of the New Brunswick Department of Natural Resources, the province assuming responsibility for measuring songbird responses on transects 3,5,6,7, 16, and 21 (Table 1). Estimates of the immediate effects of several of the major spray regimes are reported here, analysis and interpretation of the results being those of CWS alone.

Method

Spray operations were conducted by two organizations, Forest Protection Ltd., a provincial crown corporation, and J.D. Irving Ltd., Woodlands Division, a private company. Most of the spraying was carried out by Grumman Avenger (TBM) aircraft, with VFR track guidance system as described by Flieger (1964). One-fifth of the total area was sprayed by 4-engined DC-6 aircraft flying singly and equipped with an inertial guidance system. Most of the remaining area was sprayed by Rockwell Thrush Commander aircraft fitted with rotary atomizers, and by twin-engined Curtis–Wright C-46 aircraft operating in pairs (lead aircraft equipped with inertial guidance system). Very small parcels of land were sprayed by Cessna AGwagon aircraft. Spraying took place during stable air conditions, about two-thirds of the total area being treated in morning operations and the remainder during the evening.

We assessed the immediate response of birds to the sprays in the manner described by Pearce *et al.* (1976). Repeated counts of singing male birds were made on transects along woods roads before and after spray treatment. Transects were each 5 km long and the counts took about three hours (05:30 to 08:30) to complete. No more than one observer was assigned to a given transect. We oriented transects as much as possible across spray emission lines to permit better interpretation of possibly uneven applications of spray.

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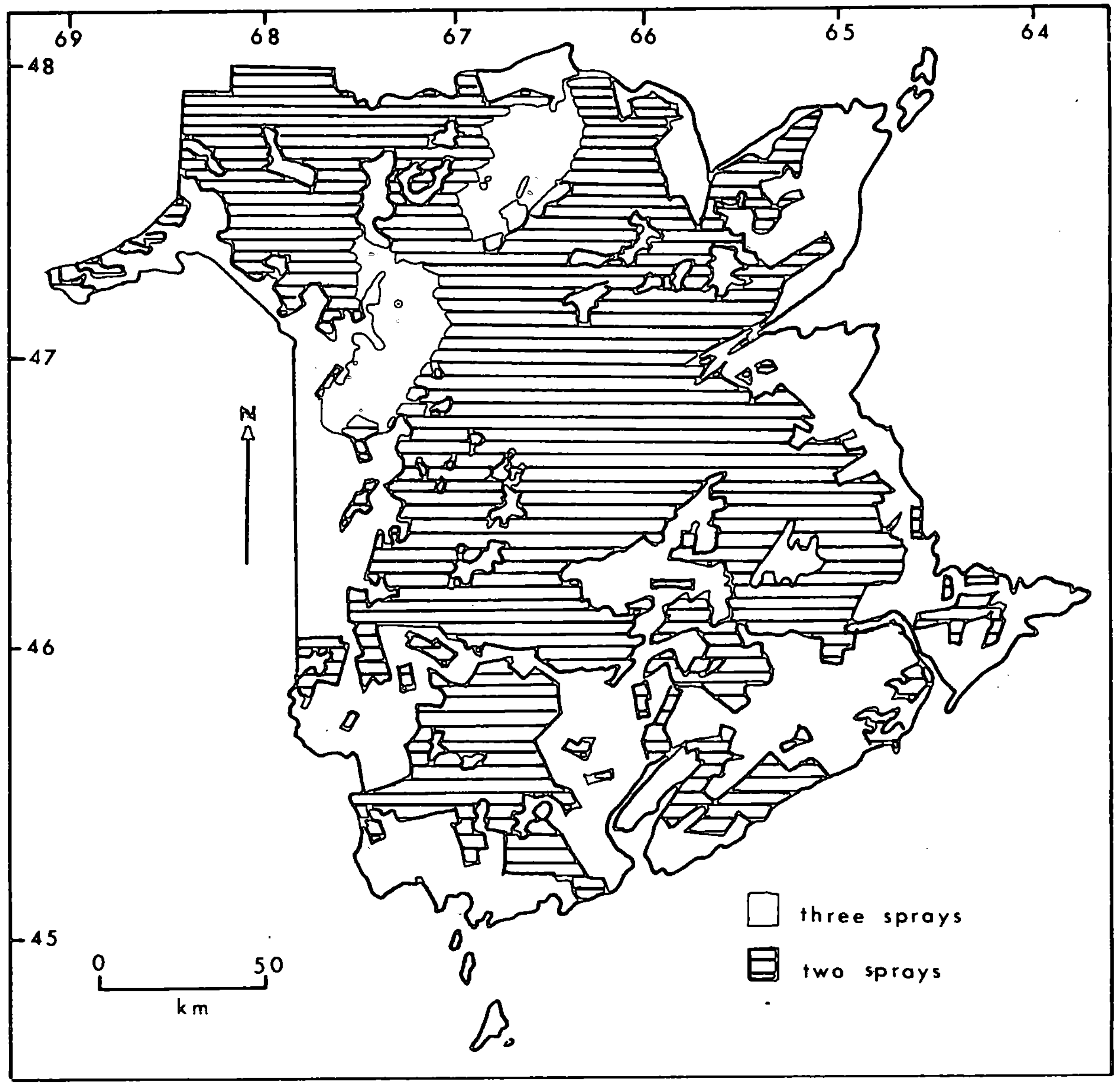
Figure 1
Area sprayed in New Brunswick during 1976 larviciding operations against spruce budworm



Irregularity of spray distribution could result from many factors, including overlaps of and gaps between spray swaths, a phenomenon not infrequently observed during aerial forest spraying in New Brunswick in the past. Also, random spraying back into the block took place to use unspent insecticide on completion of spray sorties.

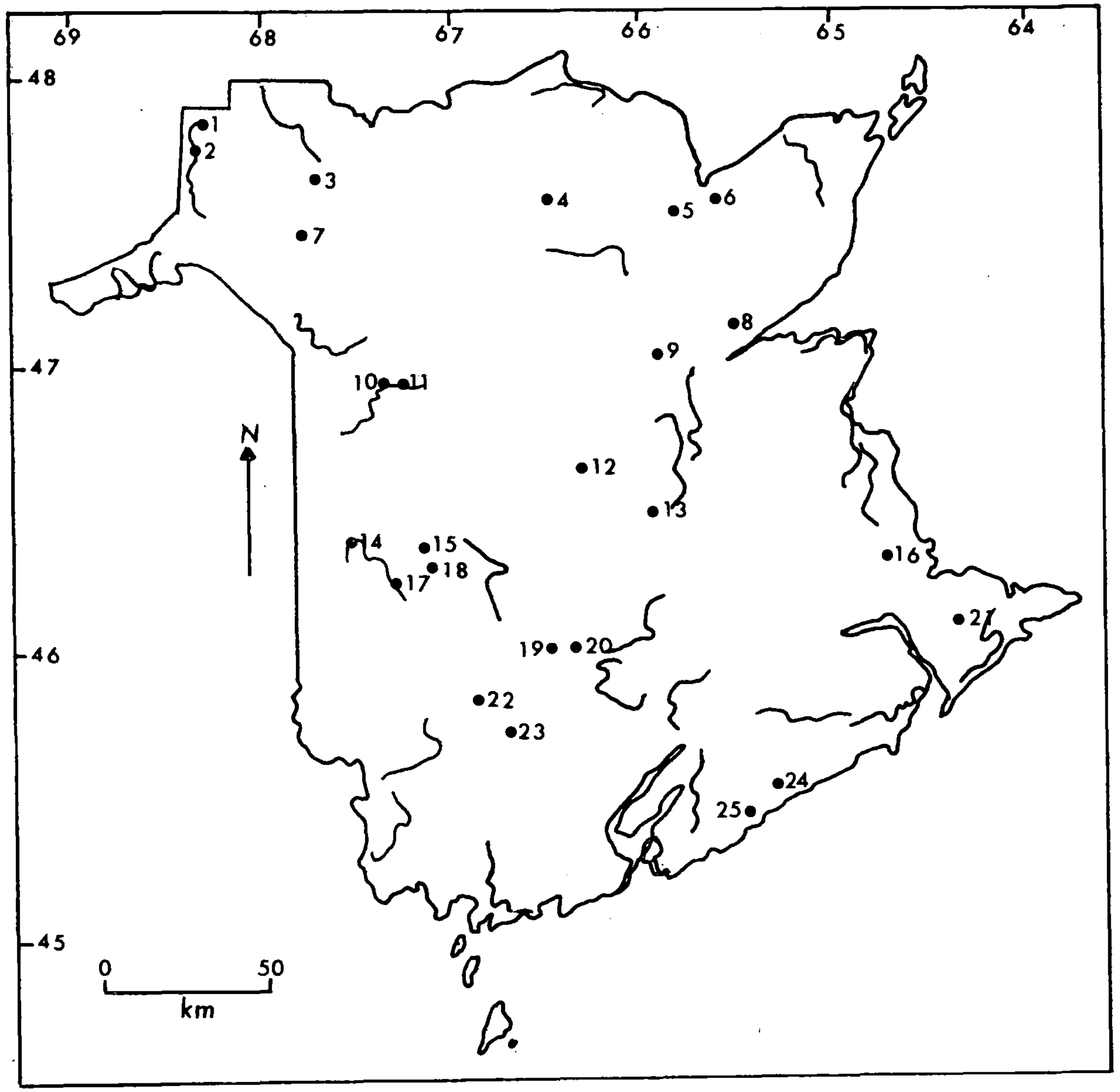
We surveyed 23 transects in seven of the largest spray regimes, which represented 89% of the total area sprayed. The scheduling for insecticide treatment of so much of the province's spruce–fir forest severely limited areas suitable for check transects. Only one such transect was run, that being in unsprayed forest to the west of and upwind from the spray zone. We also made counts of singing males along three 5-km transects in a small area (Acadia Forest Experiment Station) subjected to experimental larviciding very early in the season before operational spraying started. Bird censuses were made along a total of 135 km on 27 transects distributed throughout New Brunswick (Figure 2), in each of the phenological zones delineated for the timing of spraying operations (Morris, Webb, and Bennett 1956), and in areas sprayed from each of the operational airstrips. Three other transects had to be abandoned because of last-minute redrawing of spray block boundaries. Bird surveys carried out in rain or when the estimated wind speed exceeded 19 km/h (force 3, Beaufort scale)—one-tenth of the 300 surveys made—were subsequently rejected, because rain and excessive

Table 1
Synopsis of major insecticidal treatments during 1976 aerial spray operations against spruce budworm larvae in New Brunswick

Spray regime	Insecticide	Emitted dosage* (g/ha)	Formulation	Applic. rate (ℓ/ha)	Aircraft	Area (10^3ha)	Bird transect (code†)
A	Fenitrothion	210	Emulsion	1.46	TBM	2132	3,5,15,16,17,18,19,22,24,25
	Fenitrothion	210	Emulsion	1.46	TBM		
B	Fenitrothion	210	Oil	1.17	DC-6	718	6,8,9,12,13,21
	Fenitrothion	210	Oil	1.17	DC-6		
C	Fenitrothion	280	Oil	0.58	Thrush Commander	294	7
	Fenitrothion	280	Oil	0.58	Thrush Commander		
D	Fenitrothion	210	Emulsion	1.46	TBM	128	4
	Aminocarb	70	Oil	1.46	TBM		
	Aminocarb	70	Oil	1.46	TBM		
E	Trichlorfon	560	Water	1.46	TBM	107	–
	Trichlorfon	560	Water	1.46	TBM		
F	Phosphamidon	140	Water	1.46	C-46	93	10,11
	Aminocarb	70	Oil	1.46	TBM		
	Aminocarb	70	Oil	1.46	TBM		
G	Fenitrothion	210	Emulsion	1.46	C-46	75	–
	Fenitrothion	210	Emulsion	1.46	C-46		
H	Fenitrothion	210	Emulsion	1.46	TBM	58	1,2
	Fenitrothion	210	Oil	1.17	DC-6		
I	Fenitrothion	210	Oil	0.58	AGwagon	50	–
	Fenitrothion	210	Oil	0.58	AGwagon		
J	Fenitrothion	210	Emulsion	0.73	TBM	39	23
	Fenitrothion	210	Emulsion	0.73	TBM		
K	Phosphamidon	140	Water	1.46	C-46	37	–
	Aminocarb	70	Oil	1.17	DC-6		
	Aminocarb	70	Oil	1.17	DC-6		
L	Fenitrothion	210	Emulsion	1.17	DC-6	35	–
	Fenitrothion	210	Emulsion	1.17	DC-6		
M	Aminocarb	70	Oil	1.46	TBM	21	–
	Aminocarb	70	Oil	1.46	TBM		
N	Phosphamidon	140	Water	1.46	TBM	9	20 (3 transects)
	Phosphamidon	140	Water	1.46	TBM		
	Miscellaneous (10 other combinations)					86	–
	Total					3882	

*Active ingredient.
†Figure 2.

Figure 2
Locations of songbird transects surveyed in New Brunswick during 1976 larviciding operations against spruce budworm (see numbered dots) and of the breeding bird survey routes (see short lines). Key to numbers: 1 McDonald Brook, 2 Wild Goose Lake, 3 Gounamitz River, 4 Upsalquitch River, 5 Middle River, 6 Bathurst, 7 Black Brook, 8 Russellville, 9 Estey Lake, 10 Plaster Rock, 11 Wapskehegan River, 12 Priceville, 13 Muzroll Brook, 14 Hartland (unsprayed check transect), 15 Juniper, 16 Notre Dame, 17 Becaguimec River, 18 Nashwaak Lake, 19 Burpee, 20 Acadia Forest Experiment Station (three survey routes), 21 Aboujagane, 22 Hanwell, 23 Tracy, 24 Hillsdale, 25 Porter Brook



wind tend to reduce bird singing. We devoted over 200 man-hours to searching spray zones for bird carcasses and for evidence in birds of ataxia, wing shivers, tremors, and other symptoms of cholinesterase inhibition. We made no attempt to assess insecticide deposit in any of the study areas.

Results and discussion
In keeping with the record size of the 1976 budworm spray operation, we conducted by far the broadest program to monitor effects on birds yet undertaken in New Brunswick. That exercise may represent the most extensive surveillance of a pesticide-use program yet carried out in Canada.

Monitoring effort was concentrated mainly in spray regimes A and B, which together accounted for 73% of the total area sprayed. The data derived from pre- and post-spray counts of birds along a total of 16 transects were pooled in each of the regimes and subjected to an analysis of variance to determine the significance of changes in the numbers noted. Only one transect was run in each of spray regimes C, D, and J, two in each of regimes F and H, and three in N. Since in those cases within-regime pooling of data was not appropriate, we analyzed counts by individual transect, the significance of changes being determined by the Mann–Whitney test, a suitable non-parametric treatment of small samples in which no assumptions of normality are made.

Spray regimes A and B
The effects on birds of fenitrothion sprayed as an emulsion twice by TBM at 210 g/ha (see Table 1) were unevenly distributed, as gauged from loss of song, finding of carcasses, and observation of aberrant behaviour. There were demonstrable impacts on some transects but not on others. Post-spray declines in singing Ruby-crowned Kinglets occurred on nine of the ten transects, although those reductions were not always significant. We conclude that major spray impacts occurred on transects 15, 16, and 18, on which substantial post-treatment declines were noted in the upper canopy feeders such as Northern Parula, Cape May, and Black-throated Green warblers, and also in other species, such as Magnolia and Chestnut-sided warblers, Common Yellowthroats, and American Redstarts. In one case, cold rain immediately following a spray may have further stressed exposed birds. The finding of 25 scattered dead and moribund birds in those study areas confirmed the conclusion that the spraying was harmful. One or two weeks after the second application of insecticide, there was little recovery in detected numbers of the canopy birds. An apparent recovery in some of the other species could represent an influx of additional migrants or a renewal of singing activity which had been depressed as a result of the spraying. Less-pronounced changes in the numbers of singing birds occurred on transects 5, 17, 24, and 25, especially among canopy feeders.

A double spray of fenitrothion at 210 g/ha, formulated in oil and delivered by DC-6 (see Table 1), had very little observable or measurable impact on birds on most of the six transects. We found no carcasses and only occasionally noted birds showing symptoms of intoxication. A significant overall post-spray decrease (28%) in the numbers of singing Ruby-crowned Kinglets was noted only on transect 8. During matching time periods there was also a significant decline in singing birds of that species on the unsprayed transect. No significant declines in birds grouped by foraging habitat occurred except on transect 8 in the categories designated as "ground to mid-crown" and as "wide-ranging".

We made a two-way analysis of variance of the data separately by spray regime. The transect effects were treated as random, while the time effect (before-spray vs. after-spray) was treated as fixed. The percent overall changes for grouped and for selected species are shown in Table 2. In the TBM spray zone, the decreases in singing Ruby-crowned Kinglets, Northern Parula, and Black-throated Green Warblers were highly significant. No significant decreases in singing males of those species were noted in the DC-6 spray zone. On the check transect, kinglets remained fairly constant (although, as noted above, there were fluctuations, the amount depending on which time periods are compared), while Northern Parulas increased significantly, and Black-throated Green Warblers were too poorly represented to allow data analysis. When the counts for the mid-crown to canopy birds (about 12 species) were combined, we found a slight downward trend in the TBM spray zone, probably reflecting a masking effect caused by migration into study areas of the abundant Tennessee Warbler. Of the three ground to mid-crown species considered (Magnolia Warbler, Ovenbird, American Redstart), only the Ovenbird declined significantly, and that was on transects in spray regime A. Numbers of singing Ovenbirds on the check transect fluctuated considerably, but were almost the same at the end of the study as at the beginning. The American Redstart increased substantially more in areas sprayed by DC-6 than by TBM. The Yellow-rumped Warbler, an early migrant which we consider wide-ranging in its foraging habits, declined in both spray regimes, but more so in areas sprayed by TBM. However, numbers of singing individuals of that species declined markedly on the unsprayed check transect after the end of May.

Comparison of the impact of fenitrothion (2 x 210 g/ha delivered by TBM [spray regime A] and by DC-6 [spray regime B])
Each of the 16 transects was sprayed twice and, since we had no control over the scheduling of spray sorties, we made a varying number of bird surveys during the time period before the first spray, between the two sprays, and after the second treatment. An analysis of variance was made on the arithmetic means of singing birds counted during each time period on each transect. The variables addressed were the spray technology (TBM versus DC-6), the transects within each spray technology, the time effect (before, between, and after sprays), and the interactions.

Of most interest is the interaction of the spray technology effect with the time effect. An F-test was made to compare that with the interaction of the transect effect with time. If the time effect varies significantly more between spray technologies than between transects within spray technologies, it indicates a difference in the impact of the two spray technologies on birds. That difference is shown in the group of birds we have characterized as foraging at the mid-crown to upper canopy level. For example, Parula Warbler counts are steady in the DC-6 zone, while they fall off on transects

Table 2
Effects of spray regime A (TBM) and spray regime B (DC-6) on numbers of singing males (weighted arithmetic mean) recorded on transects (Average starting and finishing dates of bird counts on TBM transects 25 May and 16 June, and on DC-6 transects 23 May and 12 June)

Foraging habitat	Spray technology	Pre-spray	Post-fenitrothion	Post-fenitrothion	% overall change
Mid-crown to canopy	TBM	90.6	89.1	87.2	-4
	DC-6	90.9	112.0	117.1	+29
Ground to mid-crown	TBM	166.0	160.9	163.9	-1
	DC-6	139.3	140.9	132.8	-5
Selected species					
Ruby-crowned Kinglet	TBM	18.1	13.4	12.4	-31*
	DC-6	24.6	25.5	22.0	-10
Tennessee Warbler	TBM	9.9	18.5	18.1	+83†
	DC-6	17.9	31.3	37.0	+107*
Northern Parula	TBM	8.3	4.5	3.9	-53†
	DC-6	3.8	3.2	3.5	-8
Black-throated Green Warbler	TBM	12.2	7.8	5.4	-56*
	DC-6	7.8	5.9	6.0	-23
Bay-breasted Warbler	TBM	9.6	9.4	10.1	+5
	DC-6	9.8	12.9	12.9	+32
Magnolia Warbler	TBM	11.7	9.4	9.3	-20
	DC-6	18.2	17.1	14.7	-19
Ovenbird	TBM	30.4	27.1	27.4	-10†
	DC-6	25.9	23.8	24.2	-6
American Redstart	TBM	12.5	13.4	15.5	+24
	DC-6	3.9	6.8	7.3	+87
Yellow-rumped Warbler	TBM	12.1	7.3	5.1	-58†
	DC-6	10.4	6.5	5.9	-43†

*Change significant at 99% level.
†Change significant at 95% level.

sprayed by TBM. Counts of Black-throated Green Warblers fall off slightly in the DC-6 zone, but much more markedly in areas where fenitrothion was sprayed by TBM. Counts of Tennessee Warblers increased more noticeably in the DC-6 zone than they did in the TBM spray zone. When counts of those three species are examined individually, they show in each case an interaction of spray technology with time which is significant at the 90% level. When the counts of mid-crown to canopy birds are combined, the impact of the two spray technologies is different at the 95% level of significance. The Ruby-crowned Kinglet means point to a similar effect, but the great variation in the effects between transects results in the attachment of statistical non-significance (89% level) to the difference between the impacts of the two spray technologies. When the data for species that forage on the ground and at levels up to mid-crown are examined, either individually or grouped, they do not point to any significant differences in impact attributable to spray technology. Birds of those species probably would be relatively less exposed to the spray.

The comparison between the two spray technologies involved analysis of bird counts made on a total of 80 km of transect. The 16 transects were widely distributed, mostly in southern and central regions of the province. Such a comparison should minimize the masking influence of birds migrating into and out of study areas at the time of sprays. When the main operational larviciding started, only a few species of birds were present in appreciable numbers on study areas. Among the most commonly represented were Ruby-crowned Kinglet, Yellow-rumped Warbler, Ovenbird, Northern Waterthrush, and White-throated Sparrow. During the last days of May, a wave of migrant warblers arrived, including Tennessee, Northern Parula, Magnolia, Black-throated Green, Blackburnian, and Bay-breasted warblers, and American Redstart. Many of the early sprays in southern parts of the province took place at that time. Since in all cases where decreases in bird counts occurred the declines were much more marked after TBM sprays, the minimum spray impact would appear to be the difference between the data derived from the TBM transects and those from the DC-6 transects, on the assumption that all decreases on DC-6 transects were due to natural causes. That supposition seems valid in the light of evidence presented above. Thus the overall decreases in Ruby-crowned Kinglet, Northern Parula, and Black-throated Green Warblers on TBM transects would be, respectively, 21, 45, and 33%, The Ruby-crowned Kinglet represents a special case since it is an early migrant which was established on territory well before the time that the sprays took place. After a decline very early in May and an unexplainable peak at the end of the month, numbers of that species remained fairly constant on the check transect. For those reasons, we consider 21% to be the minimum amount by which that species was reduced in spray regime A.

We suggest that, in addition to insecticide identity and dosage, other inter-related features of forest spraying could be quite important in an assessment of hazard to birds, and should be considered in attempting to account for the apparent differences of impact between the TBM and DC-6 sprays: (a) spatial regularity of insecticide emission, (b) degree of canopy penetration by the spray cloud, (c) differences in spray droplet size spectra, and (d) method of formulation, e.g. oil solution, water solution, or oil-in-water emulsion, as well as consistency of correct formulation. Horizontal and altitudinal positioning of spray aircraft (dependent largely on guidance systems), and meteorological conditions at the time of insecticide application would influence (a) and (b) considerably.

Spray regime C

The effect of a double application of fenitrothion at 280 g/ha was assessed on transect 7. Thrush Commander aircraft delivered the insecticide. Bird survey data are summarized in Table 3. No overall downward changes in single or grouped species were significant at the 95% level of confidence, although that may have been because there was little pre-spray sampling. Several declines were significant at the 90% level, but those declines were matched on the unsprayed check transect. The spray regime accounted for about 8% of

Table 3
Effect of spray regime C on numbers of singing males (median) recorded on transect 7

Foraging habitat	Pre-spray 2 counts 2–3 June	Post-fenitrothion 3 counts 4–8 June	Post-fenitrothion 4 counts 10–23 June	% overall change
Mid-crown to canopy	97	79	58*	-40†
Ground to mid-crown	101	84	77.5	-23†
Wide ranging	65	54	51	-22
Selected species				
Ruby-crowned Kinglet	17	12	11*	-35†
Tennessee Warbler	22.5	11	8	-64†
Black-throated Green W.	8.5	6	2*	-76†
Unsprayed check transect				
Foraging habitat	2 counts 31 May–3 June	2 counts 6–8 June	4 counts 11–22 June	% overall change
Mid-crown to canopy	117.5	91.5	77.5	-34†
Ground to mid-crown	141	133.5	126.5	-10†
Wide ranging	48	41	51.5	+7
Selected species				
Ruby-crowned Kinglet	15.5	14	11.5	-26
Tennessee Warbler	48.5	24	15	-69†

*Change from previous series of counts significant at 95% level.
†Change significant at 90% level.

Table 4
Effect of spray regime D on numbers of singing males (median) recorded on transect 4

Foraging habitat	Pre-spray 3 counts 8–10 June	Post-fenitrothion 5 counts 11–18 June	Post-aminocarb 1 count 19 June	Post-aminocarb 3 counts 20–22 June	% overall change
Mid crown to canopy	105	118	89	117	+11
Ground to mid-crown	106	94	83	93	-12
Wide ranging	46	33*	31	42	-8
Selected species					
Ruby-crowned Kinglet	25	25	15	14	-44†
Tennessee Warbler	46	35	25	35	-24†
Yellow-rumped Warbler	8	7	2	3	-62†
American Redstart	11	17	0	8	-27†

Unsprayed check transect

	3 counts 3–8 June	3 counts 9–15 June	1 count 18 June	2 counts 20–22 June	% overall change
Selected species					
Ruby-crowned Kinglet	13	11	15	11.5	-12
Tennessee Warbler	26	19*	17	10	-61
Yellow-rumped Warbler	3	3	3	1.5	-50
American Redstart	4	4	1	1.5	-62

*Change from previous series of counts significant at 95% level.
†Change significant at 95% level.

the total area sprayed. The monitoring effort was minimal, but the results suggest that the spray regime caused no major impact on birds despite the relatively high insecticide dosage.

Spray regime D
The influence on birds of a triple spray application—fenitrothion/aminocarb/aminocarb—by TBM fairly late in the season was assessed on transect 4. Bird survey data are given in Table 4. Only one survey could be made between the two applications of aminocarb. Relative to the check transect, no species showed a decrease attributable to fenitrothion, but a decrease in Ruby-crowned Kinglet occurred after the two aminocarb sprays.

Spray regime F
We assessed the effects of a triple spraying—phosphamidon/aminocarb/aminocarb/—on transects 10 and 11. Phosphamidon was sprayed by C-46 aircraft at 140 g/ha and aminocarb was applied twice at 70 g/ha by TBM. Bird survey results are reported in Table 5. The numbers of singing Ruby-crowned Kinglets and Yellow-rumped Warblers were reduced markedly on one transect, those declines being statistically significant. In contrast, lesser and non-significant decreases occurred in those species on the other transect. The kinglet decline took place after the phosphamidon spraying, numbers remaining fairly constant throughout the period in which the aminocarb sprays were made. Over the four-week monitoring period, Tennessee Warblers increased on both transects, doubtless contributing to the significant increase in grouped mid-crown to canopy feeders over that time interval. Interpretation of the data is difficult in the light of matching, but statistically non-significant, trends in the numbers of two of those three species on the check transect. We conclude that there was an appreciable impact of phosphamidon, at least on kinglets.

Spray regime H
The impact of a double spray of fenitrothion, delivered first by TBM and then by DC-6, was measured on two transects (1 and 2) three km apart in a late phenological zone in the northwestern corner of New Brunswick. On transect 1, Ruby-crowned Kinglets, and Tennessee, Yellow-rumped, and Blackpoll warblers decreased slightly but not significantly, but that is based on only one survey prior to the first spray. On transect 2 the numbers of all four species were reduced significantly (Table 6). Those declines occurred after the TBM spray, the numbers remaining about the same after the follow-up spray by DC-6. That evidence, albeit slight, supports other indications that TBM spraying was more hazardous to birds than DC-6 spraying.

Table 5
Effect of spray regime F on numbers of singing males (median) recorded on transects 10 and 11

Transect 10

Foraging habitat	Pre-spray 3 counts 24–27 May	Post-phosphamidon 3 counts 30 May–4 June	Post-aminocarb 4 counts 7–15 June	Post-aminocarb 3 counts 18–21 June	% overall change
Mid-crown to canopy	109	153*	137†	133	+22#
Ground to mid-crown	207	218	220	207‡	0
Wide ranging	144	165	144†	142	-1
Selected species					
Ruby-crowned Kinglet	27	20	18†∮	18	-28
Tennessee Warbler	25	48*	43.5†	35‡	+40#
Yellow-rumped Warbler	12	14	8	6	-50

Transect 11

Foraging habitat	Pre-spray 3 counts 20–28 May	Post-phosphamidon 4 counts 29 May–6 June	Post-aminocarb 2 counts 8–10 June	Post-aminocarb 3 counts 14–17 June	% overall change
Mid-crown to canopy	103	169.5*	155.5	132	+28#
Ground to mid-crown	182	204.5	191	181	0
Wide ranging	125	119	94	80	-36#
Selected species					
Ruby-crowned Kinglet	18	6.5*	8	7	-61#
Tennessee Warbler	26	59*	57	42	+62#
Yellow-rumped Warbler	29	7.5*	6	4‡	-86#

Unsprayed check transect

Foraging habitat	3 counts 24–28 May	3 counts 31 May–6 June	3 counts 8–13 June	3 counts 15–20 June	% overall change
Mid-crown to canopy	99	109	86∮	86‡	-13
Ground to mid-crown	145	141	130	135	-7#
Wide ranging	55	47	51	50	-9
Selected species					
Ruby-crowned Kinglet	19	16	12	11	-42
Tennessee Warbler	15	43	19∮	17‡	+13
Yellow-rumped Warbler	8	3	3†	3	-62#

*Change between periods 1 and 2 significant at 95% level.
†Change between periods 1 and 3 significant at 95% level.
‡Change between periods 2 and 4 significant at 95% level.
∮Change between periods 2 and 3 significant at 95% level.
#Change significant at 95% level.

Table 6
Effect of spray regime H on numbers of singing males (median) recorded on transects 1 and 2

Transect 1

Foraging habitat	Pre-spray 1 count 13 June	Post-fenitrothion 5 counts 14–18 June	Post-fenitrothion 3 counts 20–22 June	% overall change
Mid-crown to canopy	143	156	150	+5
Ground to mid-crown	98	112	99	+1
Wide ranging	39	32	25	-36
Selected species				
Ruby-crowned Kinglet	16	15	14	-12
Tennessee Warbler	18	14	11	-44
Blackpoll Warbler	28	33	21*	-25
Yellow-rumped Warbler	15	11	7	-53

Transect 2

Foraging habitat	Pre-spray 3 counts 10–13 June	Post-fenitrothion 6 counts 14–19 June	Post-fenitrothion 3 counts 20–22 June	% overall change
Mid-crown to canopy	154	151.5	131*	-52†
Ground to mid-crown	153	172.5	157*	+4
Wide ranging	81	55*	55	-32†
Selected species				
Ruby-crowned Kinglet	27	14*	13	-52†
Tennessee Warbler	17	12*	5*	-70†
Blackpoll Warbler	37	29.5	21*	-43†
Yellow-rumped Warbler	24	13*	16	-33†

Unsprayed check transect

Foraging habitat	3 counts 8–13 June	2 counts 15–18 June	2 counts 20–22 June	% overall change
Mid-crown to canopy	86	89.5	77	-10
Ground to mid-crown	130	135	121	-7
Wide ranging	51	58	50	-2
Selected species				
Ruby-crowned Kinglet	12	13	11.5	-4
Tennessee Warbler	19	18	10	-47
Yellow-rumped Warbler	3	3	1.5	-50

*Change from previous series of counts significant at 95% level.
†Change significant at 95% level.

Table 7
Effect of spray regime J on numbers of singing males (median) recorded on transect

Transect 23

Foraging habitat	Pre-spray 3 counts 16–24 May	Post-fenitrothion 2 counts 26–28 May	Post-fenitrothion 3 counts 31 May–5 June	% overall change
Mid-crown to canopy	55	63	81	+47*
Ground to mid-crown	156	162.5	144	-8
Wide ranging	59	55	48	-19
Selected species				
Ruby-crowned Kinglet	18	19.5	17	-6
Tennessee Warbler	12	24	33	+175

*Change significant at 95% level.

Spray regime J
A double spray of fenitrothion at 210 g/ha, emitted as an emulsion by TBM at 0.73 ℓ/ha (one-half the "standard" application rate) was monitored on transect 23. Bird survey data are summarized in Table 7. There was no measurable impact. The number of Ruby-crowned Kinglets remained unchanged throughout the period of monitoring. A pronounced increase in the group of birds which feed in the upper canopy was accounted for largely by the arrival of Tennessee Warblers.

Spray regime N
We obtained striking evidence of the toxicity to birds of phosphamidon during early-season spraying of that insecticide. On each of three 5-km bird survey routes sprayed by TBM with phosphamidon twice at a dosage of 140 g/ha, Golden-crowned and Ruby-crowned kinglets, and Yellow-rumped Warblers were virtually silenced (Table 8). There was little recovery two weeks after the second spray. Except for White-throated Sparrows, which apparently also were affected, few other passerines were present in significant numbers at the time of spraying. On a nearby unsprayed check route, Ruby-crowned Kinglets declined by one-third over the same period, possibly reflecting passage migration through to more northern areas, and Yellow-rumped Warblers declined only slightly. Two of the three sprayed transects were oriented mostly parallel to the flight path of the spray aircraft. But; since the effects on birds were similar on all three transects, we can discount the possibility that the impact was due to overswathing.

Summary by insecticide
(a) Aminocarb. In two of the three study areas aminocarb had little apparent impact on birds. Kinglets appeared to be affected in the third case. Sprays followed prior application of either phosphamidon or fenitrothion. Toxicological data indicate that aminocarb is slightly less poisonous to birds than fenitrothion (Schafer 1972, Hill *et al.* 1975). However, there is little comparative information on intoxication through dermal contact or inhalation. For spruce budworm larviciding, aminocarb is currently prescribed at lower dosages than fenitrothion. Under operational spray conditions, aminocarb should therefore present less hazard to forest songbirds. However, since we were unable to evaluate the impact of aminocarb separately from other insecticides, we cannot draw firm conclusions concerning its relative safety to birds.

(b) Phosphamidon. This was used in less than 5% of the area sprayed. Striking reductions of singing birds followed early-season spraying of that insecticide by TBM. When applied at the same dosage by C-46, it appeared to do much less damage. However, in the light of the known risks to birds associated with the use of phosphamidon at dosages which seem to be required for an acceptable measure of forest protection, we believe that that insecticide should not be used for spruce budworm larviciding purposes.

(c) Fenitrothion. There was a barely discernible impact when fenitrothion was sprayed by DC-6. At the same dosage, that insecticide sometimes had an appreciable influence on birds when it was delivered by TBM aircraft. Clearly, factors in addition to dosage should be considered in evaluating the potential hazard of forest insecticides to birds. The margin of safety for birds exposed to fenitrothion, sprayed at prescribed budworm larvicidal dosages, apparently may be quite narrow.

Casualty estimates
Singing in defence of territory is an integral part of passerine reproductive behaviour. It seems most unlikely that a bird which is inhibited from singing at the onset of the breeding season could otherwise function normally in physiological terms. We consider the cessation of song at such a critical period to be evidence of a serious disruptive effect resulting from spraying. We therefore use the term casualty to include

Table 8
Effect of spray regime N on numbers of singing males (median) recorded on survey routes 20A, B and C

Survey route A

Selected species	Pre-spray 5 counts 5–10 May	Post-phosphamidon 3 counts 11–13 May	Post-phosphamidon 2 counts 16–27 May	% overall change
Golden-crowned Kinglet	7	0*	0	-100†
Ruby-crowned Kinglet	67	2*	0.5	-99†
Yellow-rumped Warbler	26	11	4	-85†

Survey route B

Selected species	Pre-spray 3 counts 5–7 May	Post-phosphamidon 2 counts 12–13 May	Post-phosphamidon 2 counts 16–26 May	% overall change
Golden-crowned Kinglet	5	0	0	-100
Ruby-crowned Kinglet	34	2.5	1	-97
Yellow-rumped Warbler	16	16	2	-88

Survey route C

Selected species	Pre-spray 5 counts 5–10 May	Post-phosphamidon 3 counts 11–13 May	Post-phosphamidon 2 counts 16–27 May	% overall change
Golden-crowned Kinglet	14	5	0	-100†
Ruby-crowned Kinglet	45	23*	5.5	-88†
Yellow-rumped Warbler	25	23	4.5	-82†

Unsprayed check route

Selected species	2 counts 6–7 May	2 counts 12–13 May	3 counts 20–25 May	% overall change
Golden-crowned Kinglet	2	1.5	2	0
Ruby-crowned Kinglet	24	18.5	16	-33
Yellow-rumped Warbler	4.5	6	4	-11

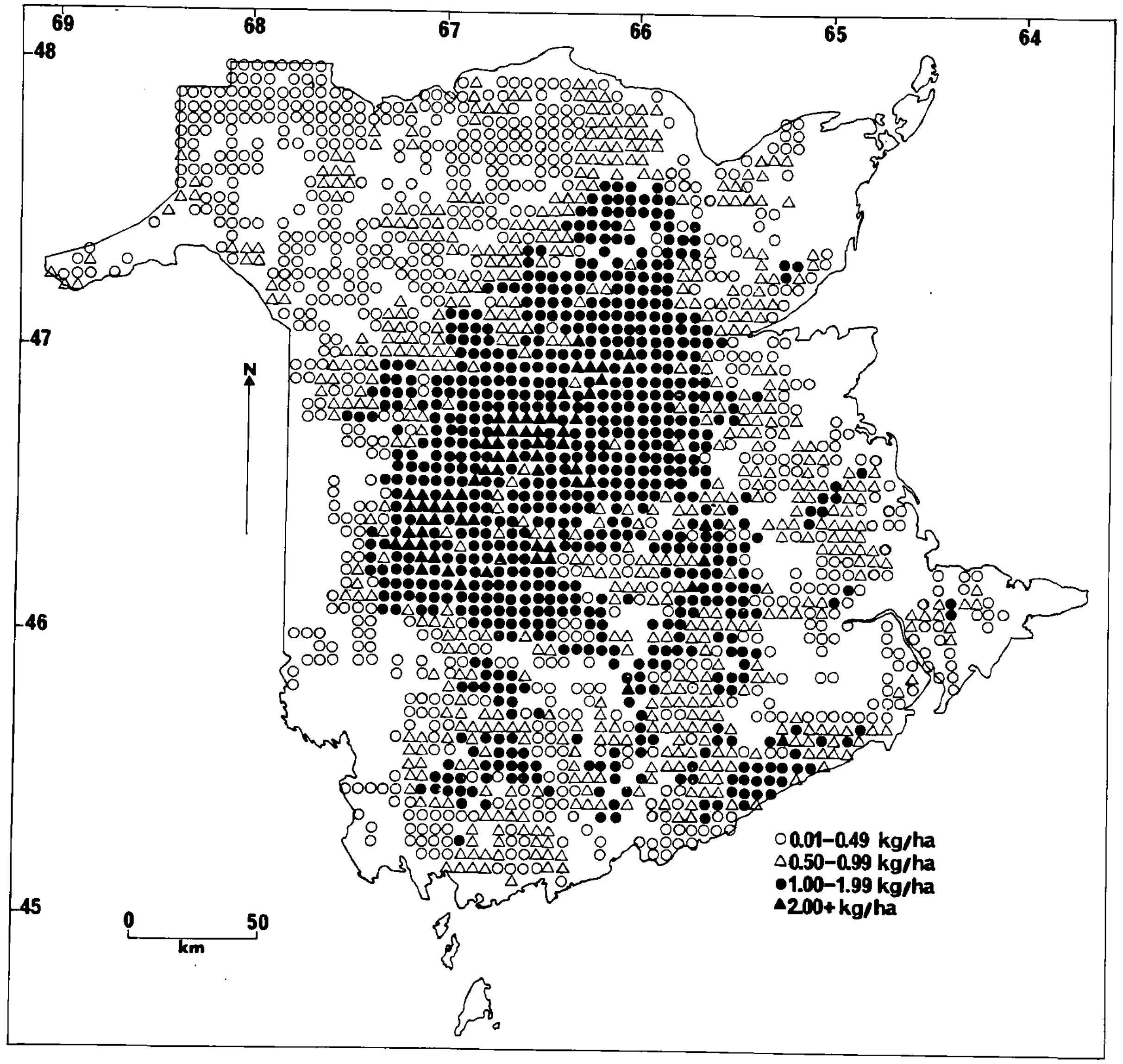
*Change from previous series of counts significant at 95% level.
†Change significant at 95% level.

birds which stop singing after exposure to spraying, as well as those actually found killed by the sprays. The transect method of measuring changes in bird populations favours the underestimation of casualties, since the observer tends to hear a greater proportion of singing birds when fewer are present or singing, and thus any decline in song is masked.

We were unable to investigate the few local reports of bird mortality received from the public. We recovered about 30 dead or moribund birds, nearly all of which were males, from study areas in fenitrothion spray zones, all within one or two days of spray application. Fenitrothion was measured in all samples when they were analyzed by gas–liquid chromatography. Low levels of fenitro-oxon were also detectable in some samples. The specimens showed measurable depression of brain cholinesterase activity. Thus it seems reasonable to conclude that those birds were spray victims. Twelve species, particularly Black-throated Green and Blackburnian warblers, were represented among casualties retrieved from spray zones. Most casualties were from TBM spray blocks, and some were found in small blocks sprayed by AGwagon. Among birds showing evidence of poisoning, but not captured, were Ruby-crowned Kinglets, Cape May Warblers, Magnolia Warblers and, along roadsides, occasional Dark-eyed Juncos and Chipping Sparrows. We assume that in cases of acute poisoning only a very small fraction of dead and severely incapacitated birds is found by searchers.

Experience has shown the Ruby-crowned Kinglet to be sensitive to forest sprays. It is one of New Brunswick's smallest birds and is distributed throughout the province. Although found in most forest types, it prefers coniferous stands, where it is essentially an upper-canopy bird—if the canopy is closed, it may be fairly abundant. Its song is readily recognized. It is an early migrant, arriving in the south of the province from mid to late April, and is well established before operational larviciding against spruce budworm normally begins. The kinglet is thus not subject to the confounding influence of migration, which makes response to early sprays so difficult to interpret among populations of many other species. For those reasons, we consider it to be a good indicator species, probably representative of those upper-

Figure 3
Cumulative emission amounts of fenitrothion (active ingredient) in New Brunswick, 1968–76



canopy birds most vulnerable to forest sprays. Some population densities of territorial male Ruby-crowned Kinglets reported from New Brunswick are as follows: 25/100 ha of fir–spruce forest (Erskine 1969), 30/100 ha of mixed coniferous–hardwood forest (Alward 1971), 32/100 ha of cedar–fir swamp forest (Tull 1973), and 35/100 ha of upland coniferous forest (Erskine 1968).

For reasons outlined above, we consider 21% to be the lowest estimate of decrease in singing kinglets in spray regime A, which represents 55% of the area sprayed. For regimes C, D, F, H, and N, the estimated decline varied from 2 to 62%, after allowing for changes on the check transect in corresponding periods. Our data do not give clear indications of losses in spray regimes B and J. Over the spray regimes monitored, comprising 89% of the area treated, the estimated reduction in singing Ruby-crowned Kinglets is about 15%. In contrast, estimated declines in that species in 1975, when regimes representing 69% of the total area sprayed were monitored, were about 78%. Thus, on a unit area basis, the 1976 spray program was about one-fifth as hazardous to Ruby-crowned Kinglets as the 1975 operation. But since the 1976 spray operation was 40% larger than the 1975 one, the overall suggestion is that total casualties among that and other canopy species were about one-quarter as great as in 1975. These figures refer to singing males, which may be representative of breeding pairs, although a certain proportion of adults present in breeding areas do not hold territories (Stewart and Aldrich 1951), and we do not know if females and non-breeders are as susceptible to the sprays as are singing males.

Long-term trends

Fenitrothion has been the major insecticide used against the spruce budworm in New Brunswick since the late 1960s. In the last decade, most of the budworm-susceptible forest in New Brunswick has been sprayed one or more times with that insecticide, a cumulative amount exceeding 2.0 kg/ha having been released over some central parts of the province (Figure 3).

There has been some speculation as to the long-term effects of the spraying on populations of forest songbirds. Breeding bird surveys conducted annually in New Brunswick since 1966 have included point counts of birds every 0.8 km on randomly located routes 40 km long (Robbins and Van Velzen 1967). The distribution of the routes is shown in Figure 2. Nearly all routes received some fenitrothion spray at some time during the 10-year period. Annual index numbers for populations of 10 species of forest birds, based on those surveys, give no indication of any downward trends during the period of use of fenitrothion (Table 9). Those data are not absolute numbers but only indices to changes between pairs of successive years (Erskine 1978). Upward trends in the data for seven of the 10 species presented in Table 9 are indicated. The samples of Blackburnian Warblers were so small that trends in that species are not convincing. Since the other two exceptions (American Robin and White-throated Sparrow) are the only ones that are not strictly insectivorous, one may speculate that insectivores had been depressed in 1967. Indeed, May 1967 was much colder and wetter than normal, and numbers of some of those insect-eating birds had decreased compared with 1966 (Erskine 1978).

The New Brunswick breeding bird surveys show trends closely paralleling those for the Maritime Provinces as a whole. We recognize the shortcomings of the data, but tentatively conclude that the natural resilience of songbird populations has in the long run compensated for the sometimes locally substantial, short-term setbacks that have been attributed to forest spraying.

Table 9
Indices to population changes in 10 species of forest birds in New Brunswick, 1967–76, based on reference year 1973

Species	1967	(14)*	1968	(15)	1969	(15)	1970	(16)	1971	(18)	1972	(16)	1973	(15)	1974	(14)	1975	(13)	1976
	Index to change‡																		
American Robin	119		115		115		116		119		119	†	100		102		101		111
Ruby-crowned Kinglet	72		64		69		64		78		83		100		87		77	†	117
Tennessee Warbler	33		41		46		36		49	†	70		100		105	†	78	†	108
Magnolia Warbler	47		55		61		63		78		76		100	†	77		85	†	110
Black-throated Green Warbler	54		61	†	71		63		83		87		100	†	60		87		104
Blackburnian Warbler	88		46		71		93		85		85		100		116		63		57
Bay-breasted Warbler	26		26		30		33		43	†	87		100	†	59		64		64
Ovenbird	51		46		58	†	71		71	†	97		100		120	†	83		87
American Redstart	71		73		74		85		89		99		100		104		96		83
White-throated Sparrow	124		113		114		121		116		122	†	100		102		101		97

*Number of comparable routes.
†Changes significant at 95% level.
‡Based on % change in weighted means between pairs of years.

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