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Impact of aminocarb (Matacil[1]) spraying on forest songbirds in northern New Brunswick

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Abstract

The response of forest songbirds to aminocarb (Matacil) sprayed from the air against spruce budworm in northern New Brunswick was investigated in 1977. The insecticide in fuel oil was sprayed twice by TBM aircraft at a dosage of 70 g active ingredient/ha at an interval of about 5 days. That spray regime was employed on about 360 000 ha of forest, or one-fifth of the area treated with insecticides during the control operations. The impact on birds was assessed by surveys of singing males before, between and after the two sprays along walked transects totalling 40 km, by searches for casualties and by checks of nesting activity. The surveys showed no convincing evidence of spray effects on songbird populations, no incapacitated birds were observed, and nesting activity continued normally. The results, and studies of bird responses to forest spraying with aminocarb elsewhere in northeastern North America, indicate that, at conventional dosages, aminocarb presents no acutely toxic hazard to songbirds.

Introduction

The long history of aerial spray operations against spruce budworm (*Choristoneura fumiferana*) in New Brunswick spruce–fir forests has witnessed several changes in spray tactics involving delivery and emission technology and insecticides used. From 1952 through 1967, DDT was the major chemical sprayed. The organophosphorus insecticide phosphamidon (Dimecron[1]) was expected to be less harmful than DDT to aquatic organisms, but it proved highly toxic to birds at dosages required for budworm suppression (Fowle 1965, 1972). Since 1968 a second organophosphate, fenitrothion, has been the insecticide of choice. At operational dosages, it enjoyed only a narrow latitude of safety (Pearce *et al.* 1979*a*) in terms of lethal effects on songbirds.

The carbamate insecticide aminocarb (Matacil), also an anti-cholinesterase poison, was introduced into the New Brunswick forest spray scene in 1975 when it was applied twice at 52 g/ha, with an intervening spray of fenitrothion, to 62 000 ha of forest. In the extensive and complex provincial spray program in 1976, aminocarb was sprayed twice at 70 g/ha on 289 000 ha of forest land, spray regimes usually including prior use of either phosphamidon or fenitrothion. In both those years, aminocarb appeared to add little to the impact on birds caused in the same spray regimes by the organophosphates (Pearce *et al.* 1976, Pearce *et al.* 1979*a*).

Insecticide was sprayed up to three times on a total of 1 683 000 ha of New Brunswick forest in 1977. Spray regimes involving aminocarb were used on one-third of that area. One regime that included aminocarb only (a double application at a dosage of 70 g/ha) was used on 360 000 ha, providing an opportunity to determine the impact of aminocarb without the obscuring effects of other insecticides. We present here CWS's monitoring of that spray regime for its effects on songbirds.

Method

As in other years, spraying in 1977 was carried out by Forest Protection Ltd. With spray zones concentrated in central and northern parts of the province (Fig. 1), they sprayed between 23 May and 27 June, mostly during the relatively stable air conditions of early morning and late evening. Table 1 gives the technical details concerning insecticide formulation, delivery and emission for the aminocarb spray regime monitored.

We assessed the immediate response of birds to the sprays as in Pearce *et al.* (1979*a*). Concern was for both immediate and very short-term effects, i.e., up to about 10 days after treatment. Varty (1978) considered immediate effects to be "the mortality and sub-lethal responses of animals during the period of persistence of insecticides in biologically effective concentrations; this period is usually one to several days in a given habitat."

We made repeated early-morning counts of songbirds on eight transects along roads in woods before and after spray treatment. Almost all birds noted were singing males. Transects were 5 km long and surveys took about 3 hours. One observer was assigned to each transect. An unsprayed check transect, about 40 km from the farthest transect sprayed, was about 8 km downwind from the nearest spray zone. We oriented transects as much as possible across spray emission paths so as to minimize the influence of possible unevenness in swath spacing, a phenomenon we have frequently observed during aerial forest spraying in New Brunswick.

Generally wet weather prevailed throughout the spray operation, threatening execution of the program as planned. Bird surveys carried out in rain or when the estimated wind speed exceeded force 3, occasionally force 4, on the Beaufort scale—15% of the surveys made—were subsequently rejected because rain and wind inhibit both bird song and the observer's hearing. Monitoring procedures also included intensive searching for casualties and checking of nests in the spray zone.

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Figure 1
Map of New Brunswick showing areas aerially sprayed against spruce budworm in 1977

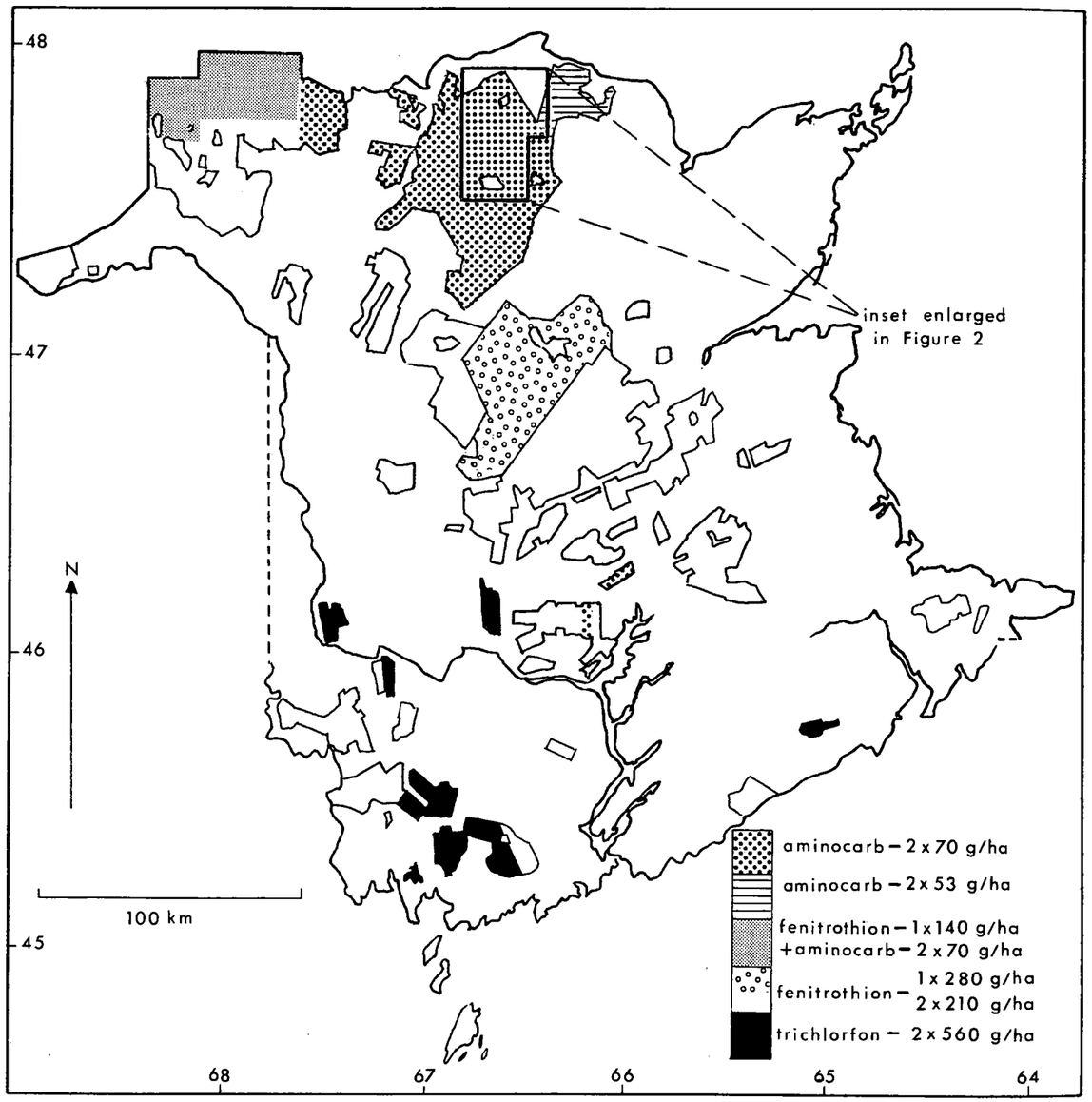


Table 1
Technical detail of spray application

Materials	
insecticide	aminocarb (Matacil), nonyl phenol formul.
dosage (active ingred.)	70 g/ha
formul. mode	oil solution
formul. % by vol.	26.7% tech. Matacil + 73.3% #2 fuel oil
applic. rate	1.46 ℓ/ha
droplet spectrum	numerical median diam. 20 μm vol. median diam. 80 μm
no. applications	2, 5-7 days apart
timing of sprays	1st just before peak 3rd larval instar
Delivery system	
spray aircraft	modif. TBM Grumman "Avenger", formation of 3
airspeed	approx. 270 km/h
emission height	approx. 30 m above tree canopy
equipment	standard boom and nozzle, T-jet nozzles, 110 10 tips
theor. swath width	approx. 400 m for formation
guidance	VFR system, flag team of 2 light aircraft (Flieger 1964)

We established bird transects in operational spray blocks 34, 40, 41, 42 and 43 (Fig. 2) in the basins of the Upsalquitch and Charlo rivers in Restigouche County. The forest is partly in the Acadian Forest Region (New Brunswick Uplands Section) and partly in the Great Lakes – St. Lawrence Forest Region (Temiscouata–Restigouche Section) (Rowe 1972.) In the former, balsam fir and black and white spruce predominate, and the tolerant hardwoods are inconspicuous. The Temiscouata–Restigouche forest lies at lower elevations, and is typified by balsam fir and white spruce in the valleys, and sugar maple and yellow birch on the hilltops. The region has a chequered fire and logging history, and much of it was sprayed against spruce budworm in 1975 and 1976. We present a general description of the forest cover traversed by each survey route in Table 2, and compare the richness of bird fauna on transects in Table 3.

We determined the significance of changes in the numbers of birds by the Mann-Whitney "U" test, an appropriate non-parametric treatment of small samples that makes no assumptions of normality.

Results and discussion

Songbird surveys

Results for each transect are summarized in Tables 4-11. We grouped birds roughly by foraging level (Table 12) with only the most abundant species given individually. Data for some less common birds (five to 10 individuals per transect) were also analyzed and are discussed.

Poor weather was a frequent problem, interrupting spraying schedules, and transects were sometimes not sprayed entirely on a given day. We made five surveys before the first spray and five after the second. During the time between treatments, we concentrated on the Charlo River, Little Popelogan, Little Upsalquitch and Caribou Road transects, necessarily at the expense of the others. That action was prompted by the aim of conducting several surveys on at least some of the transects after the first but before the second spray, coupled with the brevity of the inter-spray period and the small number of observers.

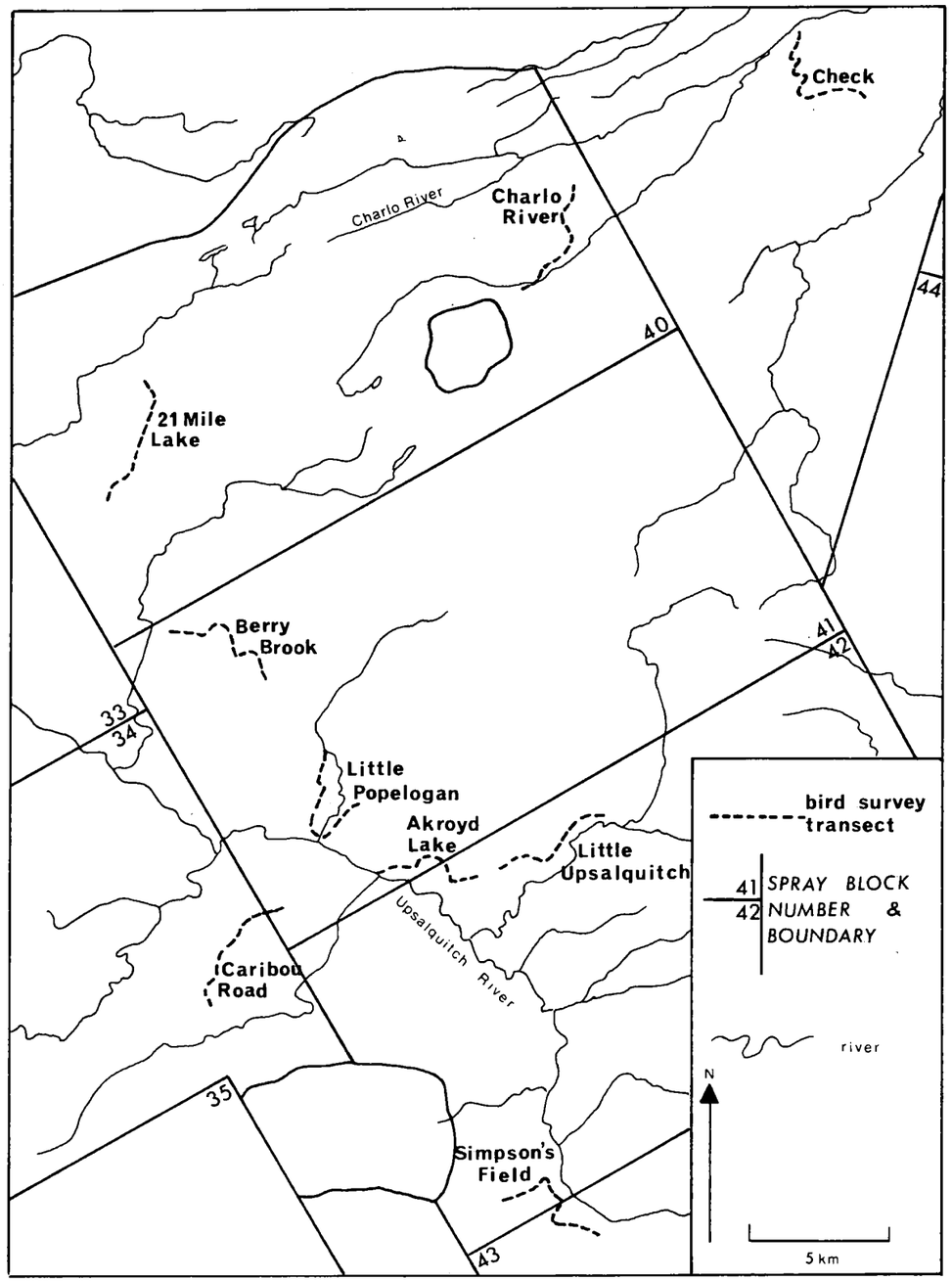
We made daily surveys on the check transect, which was probably subject to drift from spray areas. Insecticide drift modelling (Crabbe 1979) suggests that, in conditions typical of a New Brunswick forest, 84% of the spray is deposited within 0.5 km of the flight line, but the smallest droplets may still be airborne at 80 km. Pearce *et al.* (1979*b*) detected low contamination of rainwater by fenitrothion 85 km from where that insecticide was sprayed. The amount of insecticide that reached the check transect was probably very small and the risk to songbirds negligible.

Three species require special mention. Firstly, counts of singing Swainson's Thrushes increased notably on all transects (including the check route) except Little Upsalquitch. Because numbers were appreciable and could obscure possible spray-induced reductions of populations in other species, we excluded Swainson's Thrush from the group of species characterized as feeding at ground to mid-crown level.

Secondly, Pearce *et al.* (1979*a*) considered the Ruby-crowned Kinglet to be sensitive to forest sprays and useful as an indicator species. Its populations were severely reduced by unusually cold weather in parts of its winter range during the winter of 1976-77, however, and we noted it in substantial numbers only at Akroyd Lake and Simpson's Field. Analysis of the data indicated that it declined, often significantly, throughout June on all transects, including the unsprayed check one, presumably reflecting a decline in breeding activity. It is not considered to have been affected by the sprays.

Thirdly, and similarly, a notable reduction in Tennessee Warblers occurred throughout June on all transects including the check one. This bird arrives in the spring about a month later than the Ruby-crowned Kinglet, and the decline may reflect subsequent migration out of the region. Tennessee Warbler populations were particularly high, at least initially, at Little Popelogan, Akroyd Lake and Simpson's Field. Since declines were universal, we concluded that they were not due to spray influences, and we excluded the Tennessee Warbler from the canopy-foraging group of species during data analysis.

Figure 2
Map showing location of bird survey transects



Brief comments on each transect follow.

Charlo River (Table 4)
The Bay-breasted Warbler accounted for significant inter- and post-spray declines in upper-canopy birds which were not matched on the check transect. The reduction in that species can be explained by the presence of migrants during the first two pre-spray surveys, and by a very low count on the last post-spray one. Changes in numbers of the Pine Siskin, a noted wanderer, account for most of the post-spray decline in the group of wide-ranging species. Survey data for the less-abundant American Robin, and Cape May, Black-throated Green and Canada warblers, and Northern Waterthrush showed no significant downward changes.

21 Mile Lake (Table 5)
As at Charlo River, the Bay-breasted Warbler decreased significantly, apparently owing to migration out of the area in late May. The same phenomenon may have influenced the Ovenbird. On both the 21 Mile Lake transect and the check transect, the Pine Siskin again accounted for the reduction in the group of species characterized as wide-ranging. Data for additional species analyzed—Solitary and Red-eyed vireos and Canada Warbler—showed no change.

Berry Brook (Table 6)
Apart from the Ruby-crowned Kinglet and Tennessee Warbler, discussed above, the Canada Warbler was the only relatively abundant species to undergo a reduction in terms of pre-spray/post-spray comparisons. Of the less common species analyzed—Least Flycatcher, Winter Wren, Northern Parula, Yellow-rumped Warbler and Rose-breasted Grosbeak—none declined significantly.

Little Popelogan (Table 7)
Ruby-crowned Kinglet and Tennessee Warbler declined as on other transects. No other species changed, including Winter Wren, Black-throated Green Warbler and White-throated Sparrow.

Akroyd Lake (Table 8)
The Ovenbird declined significantly overall after the first spray application. Winter Wren, Northern Parula and Blackburnian warblers, present in smaller numbers, underwent little change. The second spray treatment covered a small part of the transect on the evening of 19 June; the rest was sprayed on the evening of 23 June and on the following morning. Numbers of most species detected were low on the only inter-spray survey, possibly because of fog.

Little Upsalquitch (Table 9)
Apart from the Ruby-crowned Kinglet and Tennessee Warbler, all species, including Red-eyed Vireo, Black-throated Green and Yellow-rumped warblers, remained essentially unchanged in number throughout the study.

Caribou Road (Table 10)
The highly significant decline in the Common Yellowthroat after the first spray was paralleled on the unsprayed check transect. It was responsible for the significant change in the grouped species foraging from ground to mid-crown level. As on the Charlo River and 21 Mile Lake transects, Pine Siskins accounted for most of the changes in numbers of birds in the wide-ranging species group. Numbers of the less-abundant Least Flycatcher, Winter Wren and Canada Warbler showed no changes.

Simpson's Field (Table 11)
Pine Siskins again were responsible for declines in the grouped wide-ranging species. Negative changes in numbers of Magnolia Warblers and Ovenbirds were not matched by data from the check transect. No species other than those listed was present in sufficient numbers to permit analysis.

Occasional apparent population reductions, e.g., Canada Warbler at Berry Brook, Ovenbird at Akroyd Lake and Simpson's Field, and Magnolia Warbler at Simpson's Field, cannot readily be explained by migration from the area early in the study or by waning breeding activity during it. Those declines were not highly significant, occurred on transects where only one inter-spray survey was made, and are contrary to the evidence elsewhere that those species were unaffected. We conclude that the surveys do not demonstrate any population shifts clearly attributable to the insecticide treatments.

Casualty searches
During the first two days after insecticide application, we spent about 60 man-hours searching the spray zone intensively for evidence of toxic effects on birds. Even along roads, it is very difficult to find small dead birds in the type of forest sprayed, and none were located. Others working there reported no dead birds or unusual bird behaviour in the aminocarb spray zone. Since no birds were seen showing acute symptoms or manifestation of symptoms of aminocarb poisoning, as described by Tucker and Crabtree (1970), we assume that no significant mortality occurred. During a short period of cold, wet weather in mid-May, prior to the start of spray operations in the region, we did, however, note aberrant behaviour in some insectivorous birds.

Nesting integrity
Studies of nesting success can help in assessing the impact of insecticides on forest birds (e.g., DeWeese *et al.* 1979, Richmond *et al.* 1979). Nesting success could be influenced by direct toxic effects on the young, by reduction and possible contamination of the food supply, and by death or incapacitation of parent birds. We assume that peak hatching is timed to maximum availability of food—invertebrates in the case of forest passerines. We did not look for nests systematically; however, we found 73 nests of 16 species in the aminocarb spray area, 49 of which were active at the time of spraying (Table 13). All of those remained

active after treatment, and young were fledged from 19. We do not know the outcome of the remaining 30, but there appeared to be no impact of insecticide treatment on nesting success. Three-quarters of the nests active at time of spraying contained eggs.

Our observations elsewhere in New Brunswick confirm that spruce budworm spray operations, in which the first spray application is aimed at just before the peak of the third larval instar and the second 5 days later, take place before most songbird eggs have hatched. Larviciding, therefore, is generally before the time when birds are most vulnerable.

Investigations by others

During budworm adulticiding trials in southern New Brunswick in 1976, Buckner *et al.* (1976) noted that aminocarb (a double spray as well as a triple one, all at 70 g/ha with applications at 2-day intervals) briefly reduced the activity of adult birds, and they saw a Purple Finch exhibiting symptoms typical of insecticide poisoning. They did not report on the impact of the treatments on nestlings. Germain and Morin (1979) and Germain and Tingley (1980) detected no deleterious effects on songbirds during operational aminocarb larviciding of budworm-infested forest in New Brunswick in 1978 and 1979 respectively.

During a pilot spruce budworm control project in Maine in 1975, a small sample of Evening Grosbeaks, unidentified flycatchers and American Redstarts exposed to aminocarb sprayed at 168 g/ha showed no significant brain cholinesterase inhibition (Peterson 1976). Monitoring of operational spraying of aminocarb in Quebec in the 1970s has not revealed any significant acute hazard to forest songbirds, although in one instance there were slight reductions in Ruby-crowned Kinglets, Black-and-White Warblers, Bay-breasted Warblers and Common Yellowthroats, and Evening Grosbeaks appeared to have left the area after spraying (Buckner *et al.* 1975, McLeod *et al.* 1975). It is unclear whether those effects were due to a prior application of fenitrothion.

In Newfoundland in 1977, Buckner and McLeod (1977) reported that a double application of aminocarb at a dosage of 87 g/ha and a triple spray at 70 g/ha, with spray intervals ranging from 5 to 8 days, did not damage bird populations or interrupt breeding and foraging activities.

Conclusion

Comparison of the toxicity and planned spray dosage of an insecticide with those of a better known one should have some value in predicting the ecological consequences of its use. For example, where fenitrothion is applied for forest protection in New Brunswick, we have found that harmful effects on birds are difficult to detect except where sporadic mortality occurs, possibly because of spray-swath overlap. Aminocarb is registered in Canada for use against spruce budworm at about one-half of the dosage conventionally prescribed for fenitrothion. In addition, aminocarb is somewhat less toxic to birds than fenitrothion (Hill *et al.* 1975, Schafer 1972). Aminocarb should therefore be less hazardous to birds, as was shown by the present study in the context of operational spruce budworm larviciding in New Brunswick.

The 1970s witnessed accumulation of a considerable body of experience on the performance of aminocarb under experimental and operational aerial spray conditions in the forests of eastern Canada. Dosages remained within fairly narrow limits, but formulation and spraying technology varied. Several monitoring methods were employed in assessment of avifaunal responses. The study reported here supports the evidence that, in terms of acutely toxic effects, aminocarb at prescribed dosages is not unacceptably hazardous to forest passerines. But pesticide ecology is notorious for its surprises. Further surveillance will be needed for assurance that continued use of aminocarb does not subject bird populations to more subtle pressures.

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Table 2
General description of forest cover on transects

Transect	Cover	Right of way
Charlo River	Mature hardwoods on ridge, mature softwoods at lower elevations with scattered cutovers regenerating to aspen and birch; hardwood shrubs common along roadside; several cabins in small clearings	Wide company haul road
21 Mile Lake	Very similar to Charlo River; small field; old beaver pond	Narrow logging road; transect parallel to small lake for short distance
Berry Brook	Young to middle-aged mixedwood (balsam fir, spruce, red maple, white birch); open canopy overstory of same species with scattered white pine and yellow birch	Narrow logging road
Little Popelogan	Variable; young mixedwood interspersed with stands with aspen predominating and young to pole-sized softwood stands (spruce–fir) with overstory of residual spruce and white pine	Narrow logging road; one-third of transect follows Little Popelogan Brook
Akroyd Lake	Young mixedwood with open canopy overstory of mature trees; scattered pockets of mature softwood and recent cutovers regenerating heavily to balsam fir	Narrow logging road; roadsides grown in
Little Upsalquitch	Similar to Akroyd Lake	Broad haul road
Caribou Road	Scattered middle-age softwood and mixedwood stands with pockets of intolerant hardwoods; beaver pond and boggy area with alder, willow and eastern white cedar; extensive recent cutovers with thick fir regeneration in older ones and scattered residual aspen, white birch and cedar throughout	Broad haul road with wide bulldozed shoulders; little roadside vegetation
Simpson's Field	Mature spruce–fir forest with scattered cedar and large aspen and white pine; recent clearcuts small and dispersed; alder swales common	Narrow haul road; transect crosses several small streams
(Check)	Variable; generally young mixedwood (spruce, fir, red maple and white birch); pockets of alders and large cutover with shrubs, young hardwood trees and scattered larger softwoods; beaver pond	Narrow logging road

Table 3
Distribution of passerine species on survey transects

Family	Total number of species noted during period of surveys on transect								
	Charlo River	21 Mile Lake	Berry Brook	Little Popelogan	Akroyd Lake	Little Upsalquitch	Caribou Road	Simpson's Field	Check (unsprayed)
Tyrannidae	4 (2)*	4 (1)	4 (2)	4 (1)	5 (2)	4 (2)	5 (1)	3	5 (1)
Hirundinidae	2	1	1	2	2	2	1	1	1
Corvidae	3	3 (1)	3	4	4	2	3	4	3
Paridae	2	2	2	2 (1)	2	2	2	2	2
Sittidae	1	2	1	1	1 (1)	1	2 (1)	1	1
Certhiidae	—	1	1	1	—	—	—	—	—
Troglodytidae	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1	1 (1)	1 (1)	1
Mimidae	1	—	—	—	—	—	—	—	—
Turdidae	5 (3)	5 (3)	6 (2)	6 (2)	6 (3)	6 (4)	3 (2)	2	4 (2)
Sylviidae	2 (1)	1 (1)	2	1 (1)	1 (1)	2 (1)	1	2 (1)	2
Bombycillidae	1	1	—	—	—	—	—	—	—
Sturnidae	—	—	—	1	—	—	—	—	—
Vireonidae	3 (2)	2 (2)	2 (1)	2 (1)	3 (2)	2 (1)	2 (1)	2 (1)	2 (1)
Parulidae	21 (11)	20 (11)	19 (12)	20 (11)	19 (12)	18 (14)	20 (9)	19 (9)	20 (10)
Icteridae	4 (1)	3 (1)	1	2 (1)	2 (1)	2 (1)	3 (1)	1	2 (1)
Thraupidae	1	1	1	—	1	1	1	—	1
Fringillidae	11 (6)	11 (7)	10 (4)	13 (7)	12 (4)	11 (5)	11 (4)	8 (3)	11 (4)
Total	62 (27)	58 (28)	54 (22)	60 (26)	59 (27)	54 (28)	55 (20)	46 (15)	55 (19)

*Number of species noted consistently on surveys is shown in parentheses.

Table 4
Effects of spray on grouped and individual songbird species on Charlo River transect (first spray 14 June pm, second 19-20 June)

Foraging habitat	A. Pre-spray: May 30 (30)*	June 1 (1)	June 9 (9)	June 12 (12)	June 14 (14)	Mean	B. Inter-spray: June 15 (15)	June 16 (16)	June 17 (17)	June 18 (18)	Mean	C. Post-spray: June 23 (23)	June 25 (25)	June 27 (26)	June 29 (29)	July 1 (1)	Mean	% change & signif. A-B	B-C	A-C
	No. of birds						No. of birds					No. of birds								
Upper canopy†	125	137	99	109	114	116.8	114	128	121	114	119.2	100	96	105	104	78	96.6	+2.1	−19.0§	−17.3#
	(34)*	(61)	(42)	(66)	(46)	(49.8)	(47)	(57)	(58)	(48)	(52.5)	(49)	(48)	(43)	(65)	(44)	(49.8)	(+5.4)	(−5.1)	(0)
Ground to mid-crown‡	151	162	150	150	151	152.8	160	153	173	165	162.8	146	148	161	155	142	150.4	+6.5	−7.6	−1.6
Wide-ranging	77	73	58	67	62	67.4	54	68	72	62	64.0	57	51	71	55	53	57.4	−5.0	−10.3	−14.8#
	(38)	(28)	(20)	(39)	(32)	(31.4)	(26)	(33)	(25)	(27)	(27.8)	(26)	(23)	(22)	(32)	(34)	(27.4)	(−11.5)	(−1.4)	(−12.7)
Selected species																				
Least Flycatcher	10	10	15	9	10	10.8	16	11	17	14	14.5	14	9	13	8	7	10.2	+34.3#	−29.7	−5.6
Swainson's Thrush	13	15	20	20	27	19.0	33	29	42	29	33.3	31	25	44	40	32	34.4	+75.3§	+3.3	+81.1§
	(4)	(8)	(4)	(7)	(6)	(5.8)	(6)	(7)	(6)	(5)	(6.0)	(9)	(8)	(10)	(19)	(7)	(10.6)	(+3.4)	(+76.7§)	(+82.8§)
Northern Parula	8	11	7	11	12	9.8	12	8	10	11	10.3	9	9	10	15	11	10.8	+5.1	+4.9	+10.2
Magnolia Warbler	20	26	19	35	24	24.8	17	24	24	23	22.0	16	22	21	23	19	20.2	−11.3	−8.2	−18.5
Bay-breasted Warbler	61	58	32	40	37	45.6	34	39	44	34	37.8	29	31	34	32	13	27.8	−17.1	−26.5#	−39.0#
	(20)	(28)	(14)	(23)	(21)	(21.2)	(19)	(20)	(19)	(21)	(19.8)	(19)	(19)	(18)	(24)	(17)	(19.4)	(−6.6)	(−2.0)	(−8.5)
Ovenbird	22	17	15	17	15	17.2	16	18	16	14	16.0	18	15	17	16	16	16.4	−7.0	+2.5	−7.4
American Redstart	15	20	22	20	19	19.2	19	21	18	20	19.5	21	16	29	24	21	22.2	+1.6	+13.8	+15.6
White-throated Sparrow	31	27	28	27	24	27.4	28	27	33	40	32.0	21	27	25	38	25	27.2	+16.8	−15.0	−0.7

*Dates check transect surveyed and number of birds recorded shown in parentheses.
†Tennessee Warbler excluded.
‡Swainson's Thrush excluded.
§P < .01 (Mann-Whitney U test).
#P < .05 (Mann-Whitney U test).

Table 5
Effects of spray on grouped and individual songbird species on 21 Mile Lake transect (first spray 14 June, second 19 June pm)

Foraging habitat	A. Pre-spray: May 29 (29)*	May 31 (31)	June 3 (3)	June 5 (5)	June 10 (10)	Mean	B. Inter-spray: June 19 (19)	C. Post-spray: June 20 (20)	June 24 (23)	June 26 (24)	June 28 (26)	June 30 (30)	Mean	% change & signif. A-C
	No. of birds						No. of birds	No. of birds						
Upper canopy†	89	102	65	57	77	78.0	86	75	76	62	80	57	70.0	−10.3
Ground to mid-crown‡	115	137	119	116	150	127.4	127	118	119	113	120	109	115.8	−9.1
Wide-ranging	60	56	59	58	63	59.2	49	47	50	46	51	33	45.4	−23.3§
	(37)*	(44)	(20)	(30)	(32)	(32.6)	(26)	(25)	(23)	(22)	(26)	(23)	(23.8)	(−27.0)
Selected species														
Swainson's Thrush	8	17	15	13	14	13.4	21	21	19	24	28	26	23.6	+76.1§
	(5)	(9)	(5)	(8)	(7)	(6.8)	(6)	(8)	(8)	(10)	(9)	(14)	(9.8)	(+44.1#)
Magnolia Warbler	14	13	9	16	15	13.4	12	15	16	16	15	9	14.2	+6.0
Black-throated Green Warbler	11	13	10	17	14	13.0	12	10	13	11	15	11	12.0	−7.7
Bay-breasted Warbler	30	25	12	9	10	17.2	14	10	11	10	9	5	9.0	−47.7#
	(18)	(27)	(20)	(21)	(14)	(20.0)	(18)	(19)	(14)	(18)	(19)	(14)	(16.8)	(−16.0)
Ovenbird	24	29	21	18	20	22.4	19	14	16	10	16	16	14.4	−35.7§
	(9)	(9)	(12)	(9)	(14)	(10.6)	(14)	(12)	(10)	(13)	(10)	(10)	(11.0)	(+3.8)
American Redstart	10	12	20	16	17	15.0	20	17	17	19	21	19	18.6	+24.0#
	(3)	(7)	(3)	(2)	(11)	(5.2)	(8)	(10)	(9)	(10)	(8)	(7)	(8.8)	(+69.2)
White-throated Sparrow	17	25	17	14	21	18.8	15	18	19	14	22	25	19.6	+4.3

*Dates check transect surveyed and number of birds recorded shown in parentheses.
†Tennessee Warbler excluded.
‡Swainson's Thrush excluded.
§P < .01 (Mann-Whitney U test).
#P < .05 (Mann-Whitney U test).

Table 6
Effects of spray on grouped and individual songbird species on Berry Brook transect (first spray 15 June, second 19 June)

Foraging habitat	A. Pre-spray May 29 (29)*	May 31 (31)	June 2 (1)	June 9 (9)	June 14 (14)	Mean	B. Inter-spray June 18 (18)	C. Post-spray June 23 (23)	June 26 (26)	June 28 (1)	July 2 (2)	July 4 (4)	Mean	% change & signif. A-C
	No. of birds						No. of birds	No. of birds						
Upper canopy†	61	55	53	37	56	52.4	54	43	55	46	47	46	47.4	−9.5
Ground to mid-crown‡	132	132	109	123	153	129.8	125	117	126	125	123	118	121.8	−6.2
Wide-ranging	53	51	31	33	43	42.2	29	34	51	37	35	48	41.0	−2.8
Selected species														
Swainson's Thrush	7	13	11	13	14	11.6	18	24	22	20	22	20	21.6	+86.2§
	(5)*	(9)	(8)	(4)	(6)	(6.4)	(5)	(9)	(10)	(7)	(12)	(6)	(8.8)	(+37.5#)
Tennessee Warbler	29	28	12	7	5	16.2	2	3	3	4	4	2	3.2	−80.2§
	(19)	(24)	(9)	(5)	(8)	(13.0)	(5)	(2)	(1)	(1)	(1)	(1)	(1.2)	(−90.8§)
Magnolia Warbler	33	31	20	21	27	26.4	19	23	29	31	25	26	26.8	+1.5
Black-throated Green Warbler	11	12	13	7	11	10.8	11	5	11	11	11	8	9.2	−14.8
Ovenbird	21	20	16	15	24	19.2	22	23	15	17	13	14	16.4	−14.6
Canada Warbler	18	19	14	22	20	18.6	14	16	11	17	14	12	14.0	−24.7#
	(3)	(10)	(5)	(7)	(9)	(6.8)	(12)	(10)	(9)	(4)	(7)	(5)	(7.0)	(+2.9)
American Redstart	9	6	9	6	13	8.6	8	9	11	8	12	7	9.4	+9.3
White-throated Sparrow	14	12	13	11	13	12.6	13	10	10	9	13	12	10.8	−14.3

*Dates check transect surveyed and number of birds recorded shown in parentheses.
†Tennessee Warbler excluded.
‡Swainson's Thrush excluded.
§P < .01 (Mann-Whitney U test).
#P < .05 (Mann-Whitney U test).

Table 7
Effects of spray on grouped and individual songbird species on Little Popelogan transect (first spray 15 June, second 19 June pm)

Foraging habitat	A. Pre-spray May 29 (29)*	May 31 (31)	June 2 (1)	June 9 (9)	June 14 (14)	Mean	B. Inter-spray June 16 (16)	June 17 (17)	June 18 (18)	June 19 (19)	Mean	C. Post-spray June 20 (20)	June 22 (23)	June 24 (24)	June 27 (26)	July 2 (2)	Mean	% change & signif. A-B	B-C	A-C
	No. of birds						No. of birds					No. of birds								
Upper canopy†	55	60	55	51	56	55.4	58	65	63	59	61.3	66	75	65	63	69	67.6	+10.6	+10.3	+22.0
Ground to mid crown‡	145	157	154	120	142	143.6	133	152	133	152	142.5	146	150	132	147	131	141.2	−0.8	−0.9	−1.8
Wide-ranging	69	67	83	46	52	63.4	35	58	61	54	52.0	33	44	39	70	75	52.2	−18.0	+0.3	−17.7
Selected species																				
Robin	17	11	17	15	13	14.6	14	16	17	16	15.8	14	14	9	14	10	12.2	+8.2	−22.8§	−16.4
Tennessee Warbler	42	41	38	32	33	37.2	23	34	19	19	23.8	17	15	5	14	6	11.4	−36.0#	−52.1§	−69.4§
	(19)*	(24)	(9)	(5)	(8)	(13.0)	(5)	(6)	(5)	(5)	(5.2)	(7)	(2)	(1)	(1)	(1)	(2.4)	(−60.0#)	(−53.8#)	(−81.5#)
Magnolia Warbler	27	27	28	24	24	26.0	26	24	20	27	24.3	24	31	27	31	31	28.8	−6.5	+21.0	+10.8
Blackpoll Warbler	10	13	13	12	11	11.8	15	15	17	15	15.5	16	12	15	13	10	13.2	+31.4§	−14.8#	+11.9
Ovenbird	28	23	23	18	20	22.4	20	27	23	23	23.3	19	27	19	22	15	20.4	+4.0	−12.4	−8.9
American Redstart	4	6	10	7	14	8.2	9	11	12	11	10.8	11	14	7	10	9	10.2	+31.7	−5.6	+24.4

*Dates check transect surveyed and number of birds recorded shown in parentheses.
†Tennessee Warbler excluded.
‡Swainson's Thrush excluded.
§P < .01 (Mann-Whitney U test).
#P < .05 (Mann-Whitney U test).

Table 8
Effects of spray on grouped and individual songbird species on Akroyd Lake transect (first spray 15–17 June, second 19–24 June)

Foraging habitat	A. Pre-spray						B. Inter-spray	C. Post-spray						% change & signif.
	May		June				June	June		July				
	30 (30)*	1 (1)	3 (3)	10 (10)	12 (12)		23 (23)	26 (26)	28 (29)	29 (1)	1 (2)	3 (3)		
	No. of birds					Mean	No. of birds	No. of birds					Mean	A-C
Upper canopy†	75	68	56	78	76	70.6	56	71	63	69	75	67	69.0	−2.3
Ground to mid-crown‡	162	153	150	152	152	153.8	118	155	125	174	155	144	150.6	−2.1
Wide-ranging	69	64	44	50	43	54.0	38	48	43	55	42	50	47.6	−11.9
Selected species														
Robin	19	15	11	15	15	15.0	10	14	12	12	11	12	12.2	−18.7
Swainson's Thrush	3	2	6	6	9	5.2	8	15	14	8	15	17	13.8	+165.4§
	(4)*	(8)	(5)	(7)	(7)	(6.2)	(9)	(10)	(19)	(7)	(12)	(8)	(11.2)	(+80.6§)
Ruby-crowned Kinglet	12	14	8	10	5	9.8	4	4	5	6	3	3	4.2	−57.1#
	(5)	(2)	(5)	(2)	(5)	(3.8)	(1)	(1)	(2)	(0)	(1)	(0)	0.8	(−78.9§)
Tennessee Warbler	37	37	34	21	26	31.0	11	9	8	6	8	7	7.6	−75.5§
	(22)	(9)	(7)	(5)	(7)	(10.0)	(2)	(1)	(3)	(1)	(1)	(1)	(1.4)	(−86.0§)
Magnolia Warbler	23	24	21	26	26	24.0	21	25	22	24	31	27	25.8	+7.5
Blackpoll Warbler	8	12	8	11	11	10.0	4	12	9	11	14	9	11.0	+10.0
Ovenbird	33	30	24	27	32	29.2	21	20	21	25	25	20	22.2	−24.0#
	(10)	(8)	(12)	(14)	(13)	(11.4)	(10)	(13)	(12)	(9)	(8)	(7)	(9.8)	(−14.0)
American Redstart	10	14	14	14	15	13.4	10	17	11	18	14	12	14.4	+7.5
White-throated Sparrow	33	24	26	24	22	25.8	17	25	18	27	21	25	23.2	−10.1

*Dates check transect surveyed and number of birds recorded shown in parentheses.
†Tennessee Warbler excluded.
‡Swainson's Thrush excluded.
§P < .01 (Mann-Whitney U test).
#P < .05 (Mann-Whitney U test).

Table 9
Effects of spray on grouped and individual songbird species on Little Upsalquitch transect (first spray 18 June*, second 23 June*)

Foraging habitat	A. Pre-spray						B. Inter-spray			C. Post-spray						% change & signif.
	June						June			June		July				
	3 (3)†	10 (10)	12 (12)	16 (16)	17 (17)		19 (19)	20 (20)		24 (24)	27 (26)	29 (29)	1 (1)	3 (3)		
	No. of birds					Mean	No. of birds		Mean	No. of birds					Mean	A-C
Upper canopy‡	52	61	45	57	51	53.2	64	57	60.5	65	57	58	54	44	55.6	+4.5
Ground to mid-crown§	130	143	136	158	128	139.0	161	136	148.5	138	160	173	138	129	147.6	+6.2
Wide-ranging	41	59	43	46	43	46.4	42	37	39.5	40	32	41	36	47	39.2	−15.5
Selected species																
Least Flycatcher	9	12	14	15	13	12.6	12	14	13.0	14	11	18	11	9	12.6	0
Robin	14	19	17	16	14	16.0	17	15	16.0	14	11	14	16	19	14.8	−7.8
Swainson's Thrush	15	14	14	23	22	17.6	22	20	21.0	21	17	21	21	19	19.8	+12.5
Tennessee Warbler	17	14	19	11	8	13.8	8	7	7.5	3	3	4	4	3	3.4	−75.4#
	(7)†	(5)	(7)	(5)	(6)	(6.0)	(5)	(7)	(6.0)	(1)	(1)	(3)	(1)	(1)	(1.4)	(−76.7#)
Nashville Warbler	9	7	7	9	8	8.0	8	9	8.5	9	10	8	11	9	9.4	+17.5//
Magnolia Warbler	27	26	23	21	24	24.2	31	26	28.5	25	26	29	28	23	26.2	+8.3
Ovenbird	42	45	41	50	39	43.4	43	38	40.5	36	47	46	40	41	42.0	−3.2
American Redstart	6	8	11	12	10	9.4	10	12	11.0	13	13	12	8	6	10.4	+10.6

*Small part of transect sprayed on 17 and 24 June.
†Dates check transect surveyed and number of birds recorded shown in parentheses.
‡Tennessee Warbler excluded.
§Swainson's Thrush excluded.
#P < .01 (Mann-Whitney U test).
//P < .05 (Mann-Whitney U test).

Table 10
Effects of spray on grouped and individual songbird species on Caribou Road transect (first spray 15-16 June, second 18-19 June pm*)

Foraging habitat	A. Pre-spray						B. Inter-spray				C. Post-spray						% change & signif.		
	May		June				June				June								
	29 (29)†	31 (31)	2 (2)	10 (10)	12 (12)		17 (17)	18 (18)	19 (19)		20 (20)	22 (23)	24 (24)	26 (26)	28 (1)				
	No. of birds					Mean	No. of birds			Mean	No. of birds					Mean	A-B	B-C	A-C
Upper canopy‡	36	47	29	39	37	37.6	31	30	30	30.3	35	31	34	35	29	32.8	-19.4//	+8.2//	-12.8
	(44)†	(63)	(46)	(56)	(66)	(55.0)	(58)	(48)	(50)	(52.0)	(44)	(49)	(34)	(43)	(44)	(42.8)	(-5.5)	(-17.7)//	(-22.2)//
Ground to mid-crown§	159	183	154	188	187	174.2	188	169	179	178.7	181	169	176	190	167	176.6	+2.6	-1.2	+1.4
Wide-ranging	42	37	27	29	24	31.8	26	28	30	28.0	21	23	25	14	28	22.2	-11.9	-20.7//	-30.2//
	(37)	(44)	(32)	(32)	(39)	(36.8)	(25)	(27)	(26)	(26.0)	(25)	(26)	(23)	(22)	(34)	(26.0)	(-29.3)	(0)	(-29.3)//
Selected species																			
Swainson's Thrush	14	16	9	13	24	15.2	25	22	23	23.3	23	26	34	28	34	29.0	+53.3//	+24.5//	+90.8#
	(5)	(9)	(6)	(7)	(7)	(6.8)	(6)	(5)	(6)	(5.7)	(8)	(9)	(8)	(10)	(7)	(8.4)	(-16.2//)	(+47.4#)	(+23.5//)
Magnolia Warbler	29	28	19	29	22	25.4	26	20	23	23.0	26	24	29	24	21	24.8	-9.4	+7.8	-2.4
Mourning Warbler	4	9	10	7	11	8.2	14	9	10	11.0	12	10	7	9	8	9.2	+34.1	-16.4	+12.2
Common Yellow-throat	13	12	13	12	11	12.2	7	4	3	4.7	7	6	3	6	6	5.6	-61.5//	+19.1	-54.1#
	(6)	(4)	(2)	(3)	(4)	(3.8)	(1)	(2)	(2)	(1.7)	(1)	(3)	(2)	(3)	(1)	(2.0)	(-57.9)//	(+17.6)	(-47.4)
White-throated Sparrow	71	76	61	72	79	71.8	83	77	71	77.0	70	71	75	74	71	72.2	+7.2	-6.2	+0.6

*Small part of transect sprayed on 18 June pm.
†Dates check transect surveyed and number of birds recorded shown in parentheses.
‡Tennessee Warbler excluded.
§Swainson's Thrush excluded.
#$P < 0.1$ (Mann-Whitney U test).
//$P < .05$ (Mann-Whitney U test).

Table 11
Effects of spray on grouped and individual songbird species on Simpson's Field transect (first spray 17 June, second 23 June pm and 24 June)

Foraging habitat	A. Pre-spray						B. Inter-spray	C. Post-spray						% change & signif.
	May	June					June	June			July			
	30 (30)*	1 (1)	3 (3)	9 (9)	14 (14)		23 (23)	25 (25)	27 (26)	29 (29)	1 (1)	4 (4)		
	No. of birds					Mean	No. of birds	No. of birds					Mean	A-C
Upper canopy†	84	109	97	88	114	98.4	107	105	117	110	98	94	104.8	+6.5
Ground to mid-crown‡	79	92	105	98	124	99.6	102	106	106	100	104	99	103.0	+3.4
Wide-ranging	42	40	31	32	28	34.6	18	19	20	25	14	28	21.2	-38.7§
	(38)*	(28)	(20)	(20)	(32)	(27.6)	(26)	(23)	(22)	(32)	(34)	(15)	(25.2)	(-8.7)
Selected species														
Swainson's Thrush	13	18	8	7	28	14.8	45	48	43	41	39	46	43.4	+193.2§
	(4)	(8)	(5)	(4)	(6)	(5.4)	(9)	(8)	(10)	(19)	(7)	(6)	(10.0)	(+85.2#)
Ruby-crowned Kinglet	18	18	15	9	13	14.6	9	9	9	9	9	9	9.0	-38.4§
	(5)	(2)	(5)	(2)	(1)	(3.0)	(1)	(0)	(1)	(2)	(0)	(0)	(0.6)	(-80.0§)
Tennessee Warbler	41	51	37	35	37	40.2	19	11	18	7	9	4	9.8	-75.6§
	(22)	(9)	(7)	(5)	(8)	(10.2)	(2)	(1)	(1)	(3)	(1)	(1)	(1.4)	(-86.3§)
Magnolia Warbler	28	36	30	31	29	30.8	30	22	27	18	26	32	25.0	-18.8#
	(11)	(7)	(8)	(8)	(14)	(9.6)	(6)	(7)	(9)	(15)	(14)	(10)	(11.0)	(+14.6)
Black-throated Green Warbler	12	15	10	17	6	12.0	14	12	10	18	12	20	14.4	+20.0
Bay-breasted Warbler	33	36	47	32	53	40.2	48	43	57	48	39	31	43.6	+8.5
Ovenbird	16	11	15	15	14	14.2	11	12	8	11	15	11	11.4	-19.7#
	(10)	(8)	(12)	(10)	(19)	(11.8)	(10)	(10)	(13)	(12)	(9)	(10)	(10.8)	(-8.5)
White-throated Sparrow	21	27	35	30	46	31.8	29	35	30	31	35	28	31.8	0

*Dates check transect surveyed and number of birds recorded shown in parentheses.
†Tennessee Warbler excluded.
‡Swainson's Thrush excluded.
§$P < .01$ (Mann-Whitney U test).
#$P < .05$ (Mann-Whitney U test).

Table 12
Species of birds noted on transects, grouped by foraging level*

Upper canopy

Yellow-bellied Flycatcher	Nashville Warbler
Eastern Wood Pewee	Northern Parula
Olive-sided Flycatcher	Cape May Warbler
Golden-crowned Kinglet	Black-throated Green Warbler
Ruby-crowned Kinglet	Blackburnian Warbler
Solitary Vireo	Bay-breasted Warbler
Red-eyed Vireo	Blackpoll Warbler
Philadelphia Vireo	Scarlet Tanager
Tennessee Warbler	Rose-breasted Grosbeak

Ground to mid-crown

Ruffed Grouse	Chestnut-sided Warbler
Black-billed Cuckoo	Ovenbird
Ruby-throated Hummingbird	Northern Waterthrush
Least Flycatcher	Mourning Warbler
Black-capped Chickadee	Common Yellowthroat
Boreal Chickadee	Wilson's Warbler
Winter Wren	Canada Warbler
Gray Catbird	American Redstart
Hermit Thrush	Dark-eyed Junco
Swainson's Thrush	Chipping Sparrow
Gray-cheeked Thrush	White-throated Sparrow
Veery	Fox Sparrow
Yellow Warbler	Lincoln's Sparrow
Magnolia Warbler	Song Sparrow
Black-throated Blue Warbler	

Wide ranging

Common Flicker	Brown Creeper
Pileated Woodpecker	American Robin
Yellow-bellied Sapsucker	Wood Thrush
Hairy Woodpecker	Cedar Waxwing
Downy Woodpecker	Black-and-white Warbler
Black-backed Three-toed Woodpecker	Yellow-rumped Warbler
Northern Three-toed Woodpecker	Brown-headed Cowbird
Eastern Kingbird	Pine Siskin
Gray Jay	American Goldfinch
Blue Jay	
White-breasted Nuthatch	
Red-breasted Nuthatch	

*Occasionally-seen additional species (including waterfowl, raptors and swallows) not included in analysis.

Table 13
History of nests active in target zone at time of spray applications

	Number of nests							
				Active at spray time				
Species	Found	Predated pre-spray	Deserted pre-spray	With eggs	With young	In which incubation continued post-spray*	In which eggs hatched post-spray*	From which young fledged post-spray
Spotted Sandpiper	2	—	—	2	—	2	—	—
Yellow-bellied Sapsucker	1	—	—	1	—	—	—	1
Barn Swallow	10	1	1	8	—	5	3	—
American Robin	17	9	—	3	5	—	2	6
Hermit Thrush	2	—	—	1	1	—	1	1
Swainson's Thrush	3	—	—	3	—	—	1	2
Red-eyed Vireo	1	—	—	1	—	—	1	—
Magnolia Warbler	3	1	—	2	—	—	1	1
Yellow-rumped Warbler	2	1	—	1	—	—	—	1
Ovenbird	1	—	1	—	—	—	—	—
American Redstart	5	—	—	5	—	—	5	—
Red-winged Blackbird	7	—	3	4	—	—	4	—
Common Grackle	1	—	—	—	1	—	—	1
Dark-eyed Junco	7	2	1	2	2	—	2	2
Chipping Sprarrow	2	—	—	1	1	—	1	1
White-throated Sprarrow	9	3	1	4	1	—	2	3
Total	73	17	7	38	11	7	23	19

*Nest not followed through to success or failure.