ASSESSMENT OF THE 1971 SPRUCE BUDWORM AERIAL SPRAYING PROGRAM IN NEW BRUNSWICK AND FORECAST FOR 1972

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MARITIMES FOREST RESEARCH CENTRE
FREDERICTON, NEW BRUNSWICK

INFORMATION REPORT M-X-29

CANADIAN FORESTRY SERVICE
DEPARTMENT OF THE ENVIRONMENT

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AERIAL SPRAYING AGAINST THE SPRUCE BUDWORM IN NEW BRUNSWICK IN 1971, AND A FORECAST FOR CONDITIONS IN THE MARITIMES REGION IN 1972

SYNOPSIS

Based on surveys of defoliation, egg masses and hazard conducted in 1970, Forest Protection Limited of New Brunswick embarked on a proposed spray program of about 5.2 million acres in 1971. As new survey data came to light in the winter of 1970-71 and in the spring of 1971, about 800,000 acres were added to the plan. In all, 6,003,477 acres were treated; 4,284,727 acres receiving one application of 3 oz./acre and 1,718,750 acres receiving two applications of 2 oz./acre each of fenitrothion. In addition, 24,000 acres were treated with Zectran and 48,000 acres were treated with Matacil as a test of their operational operational capabilities.

The spring of 1971 was warm and favored the development and survival of budworm larvae. Emergent budworms were detected on 26 April in the Fredericton area. Spray operations started on 18 May and ended on 26 June 1971.

Results of Spraying

(a) Operational Spraying.

An aerial survey for defoliation conducted in July by F.P.L. and the C.F.S. delineated 1.1, 1.9, and 1.6 million acres of light, moderate, and severe defoliation, respectively, for a total of 4.6 million acres. This represents an increase of 1.2 million acres of all categories of defoliation over 1970. Generally throughout the sprayed area, there was fair success in protecting foliage. The largest single area of severe defoliation in the sprayed area was in the northern quarter of the spray plan. This area was sprayed late mainly because the weather was unfavorable for spraying. Based on ground observations, 40% of new balsam fir foliage was saved. Survival of budworms was reduced 85% on fir and 75% on spruce. These figures of foliage saved and reduction in survival are comparable to the results of past spraying programs.

In addition to spraying with an emulsion formulation, a number of spray blocks were treated early in insect development with fenitrothion in oil. In terms of reduction in survival, the results were mediocre (fir - 72%, spruce - 26%); however, protection to foliage was fair (35% of new foliage saved).

(b) Trials with Zectran and Matacil

Zectran.--Two dosages of Zectran (0.25 and 0.5 oz./acre) were tried on 12,000-acre blocks. On balsam fir, success was poor at 0.25 oz./acre (8% foliage saved, 44% reduction in survival), but was better at 0.50 oz./acre (25% foliage saved and 57% reduction in survival). However, on spruce there was virtually no reduction in insect populations.

Matacil.--Two dosages and two formulations of Matacil were tried on four, 12,000-acre blocks: (1) 0.5 oz./acre in Panasol; (2) 1.5 oz./acre in Panasol; and (3) two blocks at 1.5 oz./acre of wettable powder in summer oil. The results obtained were, by and large, inconclusive because of the many problems encountered in application of the poison. However, the results in terms of percentage reduction in survival on balsam fir were better on the wettable powder blocks than on the oil blocks. There was virtually no effect on budworm populations on spruce on all four blocks. Of the four blocks, an average of 20% of the new fir foliage was saved. Compared to fenitrothion, Matacil gave poorer results both in terms of foliage saved and effect on budworm populations.

Results of Egg-mass Surveys and a Forecast for the Maritimes Region in 1972

(a) Egg-mass Survey

In New Brunswick, counts of budworm egg masses at 1,000 locations indicated an increase in the area of high infestation from 7.9 million acres in 1970 to 9.0 million acres in 1971, and an increase of low to moderate infestation from 4.9 million acres in 1970 to 5.8 million acres in 1971. However, the area of high infestation in 1971 had a lower population density than in 1970. In general, egg densities were lower in sprayed areas. There were major extensions and increases of budworm populations in Madawaska, Victoria, Restigouche, and Gloucester counties in the north and in Charlotte County in the southwest of New Brunswick.

In Nova Scotia, egg-mass counts at 30 locations showed an intensification of the outbreaks in western Cumberland County and on the North and South mountains in Kings and Annapolis counties. The infestation does not appear to have increased in area. This might change, however, depending on the results of a survey for overwintering larvae.

In Prince Edward Island, counts of egg masses at eight locations indicate a moderate to high infestation in the western quarter of the province.

(b) Hazard to Trees in 1972

Hazard is determined from the results of egg-mass and defoliation surveys. In New Brunswick, the acreages of high and extreme hazard are 4.1 and 0.6 million acres, respectively. Another 4.0 million acres (approximately) fall in a variable hazard category. The acreage of 4.7 million acres of high and extreme hazard represents an increase of 2.1 million acres over 1970.

In Nova Scotia, hazard is high to extreme in balsam fir stands located in the infestation areas of Cumberland, Kings and Annapolis counties.

In Prince Edward Island, hazard is generally low to moderate because of the newness of the infestation.

INTRODUCTION

The 1971 aerial spraying operation was the nineteenth to protect the forests of New Brunswick from massive budworm damage. A summary of the results of operational and experimental spraying and a forecast of conditions for 1972 are presented. Analyses of data are still underway and although conclusions in the report are thought to be valid, they are subject to change. In 1971, as in previous years, there were a number of operational trials with other poisons. The results of these trials are discussed under "*Efficacy of the Spray Operation*".

ASSESSMENT OF THE 1971 AERIAL SPRAYING PROGRAM

General

Surveys for budworm egg masses in 1970 delineated 7.9 million acres of high, and 0.7 million acres of moderate infestation (Table 1). Hazard to trees was extreme on 0.4 million acres, high on 2.2 million acres, and variable on 5.4 million acres (Table 2). Based on this information, the basic spray plan proposed for 1971 included 5.2 million acres. Provision was made for the addition of areas if further surveys in 1971 indicated protection was needed.

The operational insecticide used was fenitrothion. The basic formulation was an emulsion of water, solvent oil (Aerotex), emulsifier, and fenitrothion. In addition, nine spray blocks were treated with a solution of fenitrothion and Aerotex. The spray formulations were applied on spray blocks of 12,600 acres each, with teams of three T.B.M. aircraft. Areas sprayed with fenitrothion and other poisons are summarized in Table 3 and shown in Fig. 1.

The warm spring of 1971 was generally conducive to budworm larval survival. Emerging budworm larvae were detected on 26 April in the Fredericton area, the same date as in 1970. Spray operations started on 18 May on a number of spray blocks slated for very early application of poison. Budworm larvae were, in the second instar at this date. Through May and June, insect and host-tree development progressed at an average rate and larval populations reached the peak of the sixth instar on 20 June in central New Brunswick. Spraying operations ended on 26 June.

Table 1. Areas (million acres) by categories of spruce budworm egg-mass infestations in New Brunswick, 1960-1971

Year	Infestation category: Light	Moderate	High	Total
1971	4.9	0.9	9.0	14.8
1970	4.2	.7	7.9	12.8
1969	3.0	2.0	5.0	10.0
1968	5.6	1.0	3.6	10.2
1967	4.3	.7	.8	5.8
1966	4.9	.5	1.4	6.8
1965	4.6	2.4	1.5	8.5
1964	4.4	.3	1.7	6.4
1963	3.2	.4	1.3	4.9
1962	2.7	.2	.2	3.1
1961	3.6	.8	.6	5.0
1960	3.1	.3	2.0	5.4

Table 2. Area (thousand acres) of forest in New Brunswick by hazard categories, 1970 and 1971

Hazard category[a]	Year 1970	1971
Extreme	370	575
High	2,160	4,120
Variable	5,370	4,000
Total	7,900	8,695

a. Extreme - tree mortality and top-killing is expected.

High - tree vigor will be reduced and top-killing is expected.

Variable - trees more or less in fair condition; a high insect population is present; there will be reduction in tree vigor plus some scattered top-killing; areas of high and extreme hazard are too small to be delineated.

Table 3. Synopsis of the 1971 operational spray program in New Brunswick to minimize damage by the spruce budworm, each application was applied in 0.15 U.S. gal. of formulation per acre

Insecticide and treatment	Acres
Operational	
Fenitrothion - 1 application, 3 oz. of poison (emulsion and solution)	4,212,727
- 2 applications, both 2 oz. of poison (emulsion)	1,427,750
- 2 applications, first 3 oz., second 2 oz., of poison (emulsions)	291,000
Sub-total	5,931,477
Experimental	
Zectran - 1 application of 0.25 oz. of poison (emulsion)	12,000
- 1 application of 0.50 oz. of poison (emulsion)	12,000
Matacil - 1 application of 0.50 oz. of poison (solution in panasol)	12,000
- 1 application of 1.50 oz. of poison (solution in panasol)	12,000
- 1 application of 1.50 oz. of wettable powder poison (suspension in Summer Oil)	24,000
Sub-total	72,000
Total	6,003,477

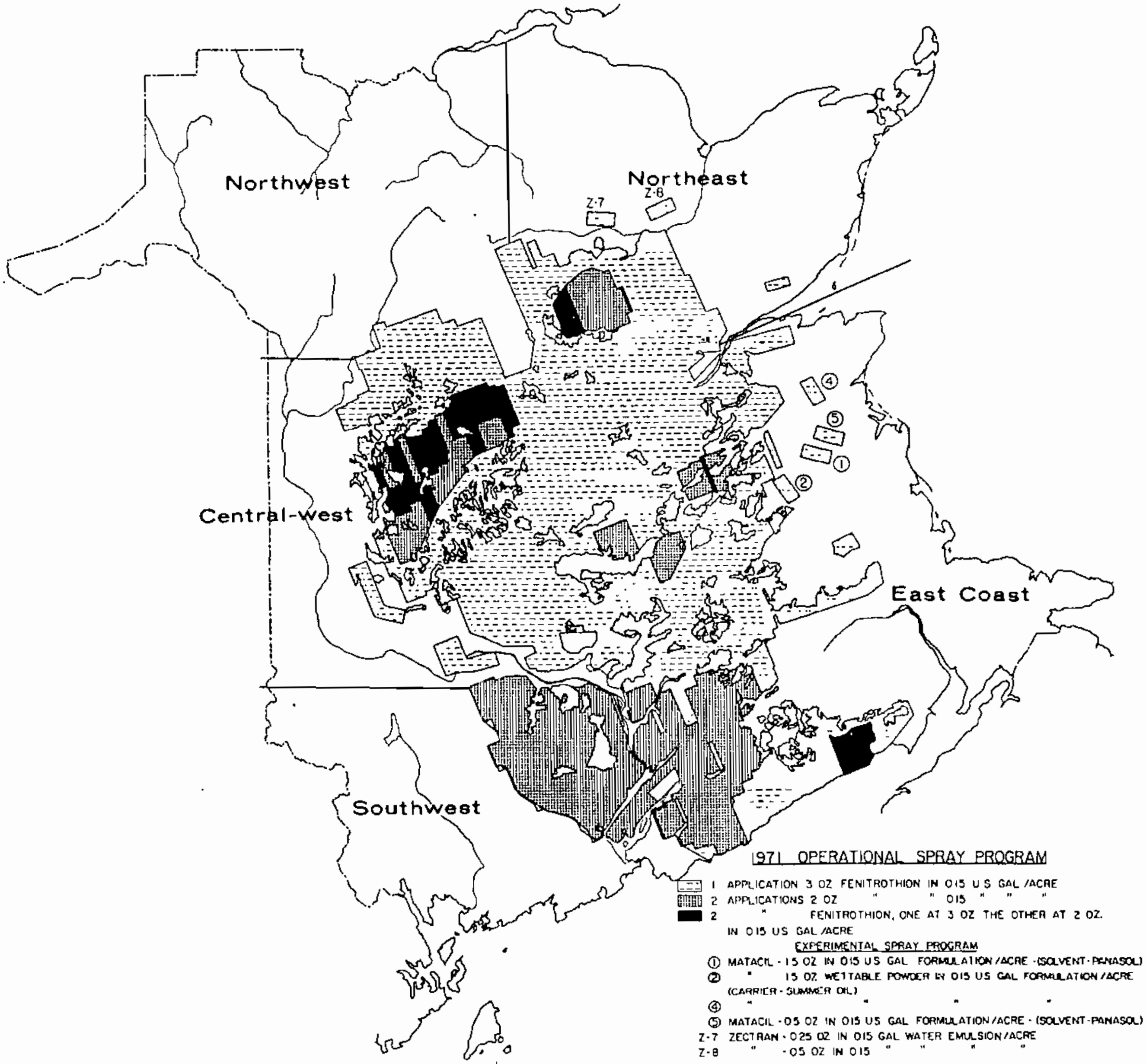

Fig. 1. Sprayed and unsprayed sectors of New Brunswick showing operational and experimental spray programs, 1971

As a result of surveys of overwintering larvae conducted in February and March 1971, and pre-spray surveys of third instar larvae and tree condition made in May 1971, about 800,000 acres were added to the spray plan. This area received 3 oz. of fenitrothion per acre.

Efficacy of the Spray Operation

The efficacy of spraying on budworm populations was estimated from pre-spray and post-spray counts on 25 plots in each of 23 spray blocks, and from a similar set of counts from 144 unsprayed plots. In all, 13 one-application and 10 two-application spray blocks were monitored. The data were grouped by insect development at time of spraying (Tables 4 and 5). Protection to trees was estimated from ground surveys of defoliation in the sampled spray blocks and at unsprayed plots. The nature and extent of damage (defoliation) were determined from an aerial survey conducted by F.P.L. and the C.F.S.

Reduction in Survival and Foliage Saved

For the 1971 operation, the average weighted reduction in survival of spruce budworm was 85% on balsam fir and 75% on spruce (red/black). Table 6 shows the relationship of these results with previous spraying programs. The mean percentage reduction in survival for blocks receiving one or two applications is as follows:

Applications	Balsam fir	Spruce
One	82	65
Two	88	77

As determined from ground defoliation estimates, 40% of the foliage was saved on balsam fir (Table 6). However, more foliage was saved in blocks receiving one application (45%) than in those having two applications (35%). Summaries of population counts, reduction in survival and foliage saved are shown in Tables 4 and 5. These tables suggest that:

(1) early application of fenitrothion in oil yields poor results in terms of reduction in survival and fair success in terms of protection of balsam fir foliage;

(2) at one application of 3 oz., the best results in terms of reduction in survival are achieved at the peak of fourth instar, but that good foliage protection is achieved at the peaks of the third and fifth instars; late spraying (sixth instar) provides little foliage protection;

(3) at one application on spruce, the best results in terms of reduction in survival are obtained at the peaks of the third and sixth instars;

Table 4. Results of spraying in terms of budworm survival, percentage reduction in survival, and percentage of foliage saved; one application of 3 oz. fenitrothion - oil and emulsion sprays

Treat-ment	Peak instar of insect	Blocks sampled	Budworm per 18-inch branch tip: Pre-spray	Budworm per 18-inch branch tip: Post-spray	Survival[a]	Reduction in survival (%)	New foliage saved (%)
			Balsam fir				
Oil	L2	3	43.3	3.5	0.08	72	35
Emulsion	L3	1	13.3	1.1	.08	72	67
	L4	5	54.5	1.7	.03	90	30
	L5	3	17.5	1.0	.06	80	52
	L6 - P	1	40.5	2.3	.06	80	3
Unsprayed	-	-	14.6	4.2	.29	0	0
			Spruce				
Oil	L2	3	13.2	1.7	.13	26	-[b]
Emulsion	L3	1	11.4	.2	.02	88	-
	L4	5	22.3	1.1	.05	71	-
	L5	3	21.9	2.1	.14	20	-
	L6	1	28.3	.4	.02	88	-
Unsprayed	-	-	14.8	2.6	.18	0	0

a. Ratio of Pre-spray/Post-spray larvae.

b. New foliage saved on spruce not recorded.

Table 5. Results of spraying in terms of budworm survival, percentage reduction in survival, and percentage of foliage saved; two applications of fenitrothion

Treat-ment	Blocks sampled	Peak instar of insect at applic. --		Budworm per 18-inch branch tip		Sur-vival[a]	Reduction in survival (%)	New foliage saved (%)
		1	2	Pre-spray	Post-spray			
				Balsam fir				
2+2 oz.	1	L3	L5	20.3	0.6	0.03	90	40
	2	L4	L6	20.6	.3	.01	97	69
	2	L5	L6	33.1	1.8	.05	83	20
	2	L6	L6	29.2	.7	.02	93	26
	1	L6	P	16.3	2.6	.16	45	10
3+2 oz.	2	L4	16	38.5	1.2	.03	90	40
Unsprayed	-	-	-	14.6	4.2	.29	0	0
				Spruce				
2+2 oz.	1	L3	L5	37.7	1.1	.03	83	-[b]
	2	L4	L6	11.5	.7	.06	67	-
	2	L5	L6	16.4	1.9	.12	33	-
	2	L6	L6	16.2	.7	.04	78	-
	1	L6	P	17.2	2.4	.14	22	-
3+2 oz.	2	L4	L6	34.6	0.9	.03	83	-
Unsprayed	-	-	-	14.8	2.6	.18	0	0

a. Ratio of Pre-spray/Post-spray larvae.

b. New foliage saved on spruce not recorded.

Table 6. Percentage reduction in survival of population, and percentage of balsam fir foliage saved by spraying, 1952-1971

Year	% reduction of survival of population		% balsam fir foliage saved
	Balsam fir	Spruce	
1952[a]	99	-[b]	7
1953	96	-	41
1954	-	-	52
1955	83	-	41
1956	89	-	25
1957	85	-	35
1958	80	-	34
1960[c]	81	42	-
1961	85	82	-
1962	82	70	-
1963	81	79	-
1964	83	65	-
1965	85	62	-
1966	88	73	-
1967	84	63	-
1968	79	70	-
1969	90	80	35
1970	76	72	65
1971	85	75	40

a. Data for 1952-58 (Webb *et al.* 1961).

b - No data.

c - Data for 1960-67 (Macdonald *et al.* 1963, 1968).

(4) at two applications, results in terms of reduction in survival were more uniform on balsam fir than one application, and the best results in terms of foliage saved were achieved when the first application was applied at the peaks of the third and fourth instars. There appears to be no real advantage in treating blocks with 3 + 2 oz. over 2 + 2 oz.

Damage to Foliage

An aerial survey for defoliation, conducted in July by F.P.L. and C.F.S., delineated 1.1, 1.9, and 1.6 million acres of light, moderate, and severe defoliation respectively, for a total of 4.6 million acres (Fig. 2). This represents an increase of 1.2 million acres for all categories of defoliation combined over 1970 (Table 7). A summary of the various categories of defoliation by county is presented in Table 7. Generally, throughout the plan there was fair success in protecting foliage. Exceptions to this were in the northern quarter of the spray plan, where two bands of severe defoliation--126,000 acres near Heath Steele Mines, and 400,000 acres from McGraw Brook in the east to Plaster Rock in the west--were detected. Both these areas were sprayed late in terms of insect development. The late spraying was a result of 4 days of weather in June favorable to budworm development but unfavorable for spraying.

Results of Trials with Zectran and Matacil

Zectran

Two dosages of Zectran (0.25 and 0.5 oz./acre) were tried on 12,000-acre spray blocks. The results of population counts, reduction in survival, and foliage saved are shown in Table 8. The results on balsam fir indicate poor success both in reduction in survival and foliage saved at 0.25 oz./acre. The results on the block treated at 0.50 oz./acre were slightly better in terms of reduction in survival, but three-times better in terms of foliage saved. However, the foliage saved is less than that obtained with fenitrothion. On spruce, there was no reduction in survival. In 1969, when Zectran was applied at 2.4 oz./acre, reduction in survival on spruce was 71% and on balsam fir 99%. This apparent inability to affect budworm larvae on spruce may be due to the short field-life of Zectran, or the habits of the budworm on red/black spruce, or both.

Matacil

The efficacy of Matacil was monitored on four 12,000-acre blocks. The dosages and formulations used were: (1) 0.5 oz./acre in Panasol; (2) 1.5 oz./acre in Panasol; (3) two blocks at 1.5 oz./acre of wettable powder in summer oil (Tables 3 and 8).

The results obtained were, by and large, inconclusive because of the many problems in applying the poison, particularly on the blocks treated with Matacil in Panasol. However, from the data that were gathered, the results in terms of reduction in survival on balsam fir were better on both wettable powder blocks than on either of the Matacil in Panasol

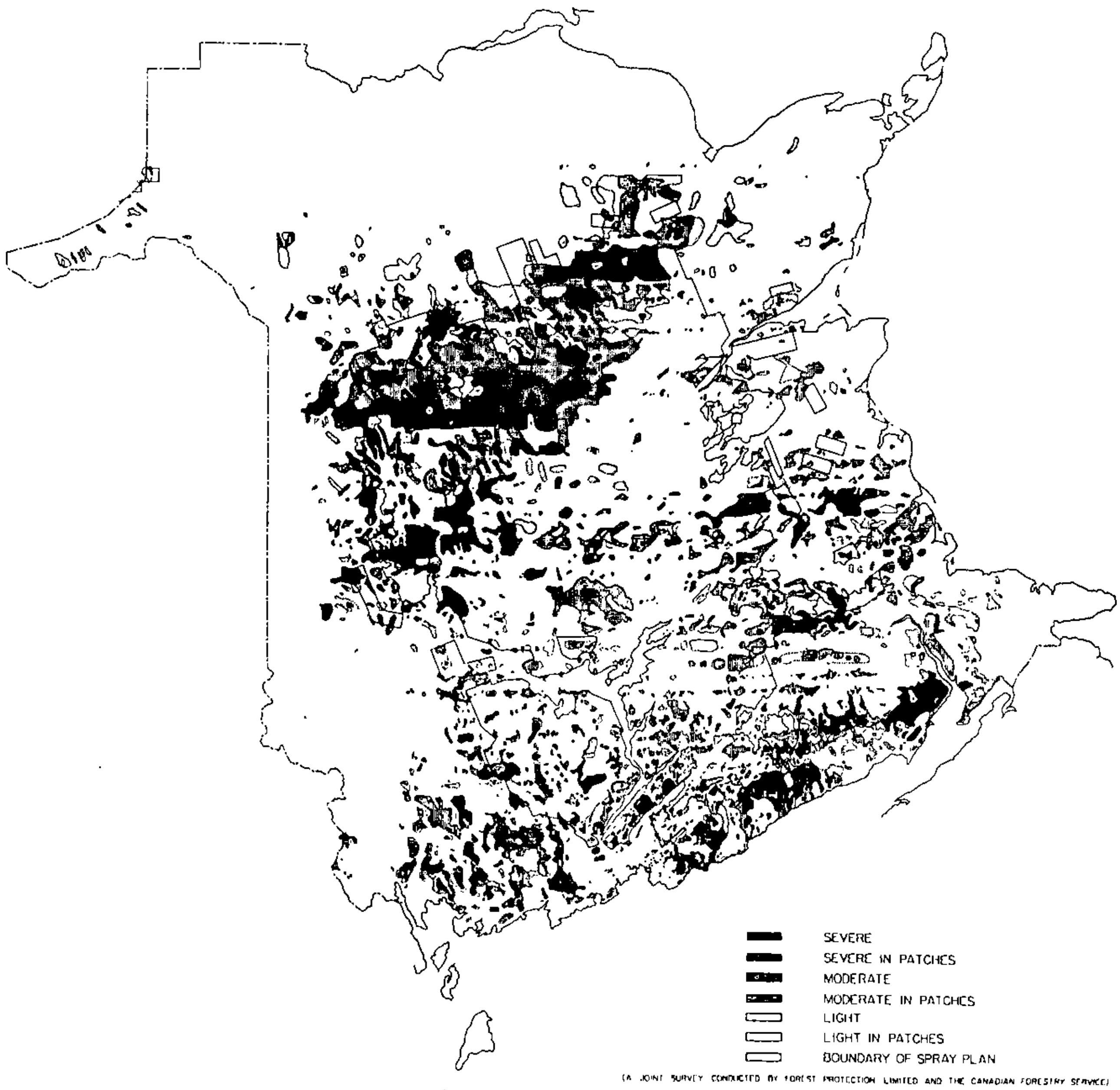

Fig. 2. Current defoliation by the spruce budworm, 1971.

Table 7. Areas (thousand acres) by categories of defoliation by the spruce budworm and by counties in New Brunswick, 1970 and 1971

	1970			1971		
County	Light	Moderate	Severe	Light	Moderate	Severe
Saint John	38.8	41.8	8.0	127.5	42.8	70.7
Albert	72.7	42.8	2.0	40.8	44.8	93.6
Westmorland	101.6	37.9	5.0	58.8	145.4	52.8
Kings	57.8	276.9	90.6	105.6	150.4	115.5
Queens	164.3	100.6	19.9	51.8	136.5	44.8
Charlotte	130.4	56.8	4.0	53.8	110.6	102.6
Sunbury	72.7	116.5	65.7	30.9	112.5	52.8
Kent	154.4	25.9	4.9	31.9	190.2	101.6
York	387.4	145.4	38.8	51.8	210.3	314.7
Northumberland	539.8	22.7	122.5	256.0	454.2	344.6
Carleton	68.7	61.7	8.9	19.9	55.8	90.6
Victoria	134.5	82.8	8.0	82.7	196.2	181.2
Madawaska	18.9	11.0	1.0	46.8	4.0	.0
Restigouche	.0	.0	.0	5.0	.0	.0
Gloucester	46.8	17.9	.0	83.7	91.6	3.0
TOTALS	1988.8	1040.7	379.3	1047.0	1945.3	1568.6

Total acreage showing some defoliation - 1969 - 3,395,500

1970 - 3,408,800

1971 - 4,560,900

Table 8. Synopsis of operational trials with various dosages and formulations of Matacil and Zectran

Treatment				Peak instar of insect on day of treatment	Budworm per 18-inch branch tip				
Poison	Dosage (oz./acre)	Formulation[a]	Spray block		Pre-spray	Post-spray	Survival[b]	Reduction in survival (%)	New foliage saved (%)
					Balsam fir				
Matacil	1.5	oil	1	L3	39.0	5.1	0.13	48	25
	.5	oil	5	L5	21.6	2.9	.13	57	15
	1.5	w.p.	2	L5	39.1	2.3	.06	76	30
	1.5	w.p.	4	L6	24.0	1.2	.05	82	6
Zectran	.25	emul.	7	L4	16.7	3.7	.22	44	8
	.50	emul.	8	L5	18.5	2.8	.15	57	25
					Spruce				
Matacil	1.5	oil	1	L3	42.9	6.6	.16	0	-[c]
	.5	oil	5	L3	19.0	7.1	.38	0	-
	1.5	w.p.	2	L5	15.1	4.0	.27	0	-
	1.5	w.p.	4	L4	24.4	3.6	.15	3	-
Zectran	.25	emul.	7	L3	12.1	1.1	.09	0	-
	.50	emul.	8	L4	15.2	1.5	.10	0	-

a. Oil - Matacil formulated in Panasol: W.p. - Matacil wettable powder formulated as a suspension in summer oil: Emul. - Zectran 2E emulsion formulated in water.

b. Ratio of Post-spray/Pre-spray larvae.

c. New foliage saved on spruce not recorded.

blocks. Foliage saved was similar on the Matacil in oil block at 1.5 oz./acre sprayed at the peak of the third instar and the Matacil wettable powder block sprayed at the peak of the fifth instar (Table 8). Both these blocks yielded better results in terms of foliage saved than the other two Matacil blocks, but none was as good as those blocks sprayed with fenitrothion. On all four Matacil blocks, there was no apparent effect on the budworm populations on red/black spruce.

RESULTS OF EGG-MASS SURVEYS AND A FORECAST FOR THE MARITIME PROVINCES IN 1972

Results of Egg-mass Surveys

In New Brunswick, counts of budworm egg masses at 1,000 locations indicate an increase in the area of high infestation from 7.9 million acres in 1970 to 9.0 million acres in 1971, and an increase of low to moderate infestation from 4.9 million acres in 1970 to 5.8 million acres in 1971 (Table 1 and Fig. 3). This increase of infestation area is in keeping with the trend set over the past 4 years. However, the area of high infestation in 1971 has a lower average population density than in 1970, and the areas of extreme infestation (400+ egg masses/100 ft^2 of foliage), are decidedly smaller than in 1970. In general, egg densities were lower in sprayed areas in 1971 (Table 9) particularly in those sprayed twice. A 7.5-fold increase in egg densities was detected in northwest New Brunswick in Madawaska and Restigouche counties and, particularly, in Victoria County (Table 9). Also, egg-mass densities showed an increase in the northeast, central-west, and southwest portions of New Brunswick. An exception is the East Coast area of New Brunswick (Fig. 1) where populations decreased slightly (Table 9). The largest areas of extreme egg-mass populations (400+ egg masses/100 ft^2 of foliage) are listed below:

(1) a wide band from Bathurst in the east to Grand Falls in the west - 1,300,000 acres;

(2) in the McGivney, Stanley, and Durham Bridge area - 115,000 acres;

(3) a patch south of Fredericton to the Bay of Fundy and east to the Saint John River - 937,000 acres;

(4) the Kingston Peninsula and Stewarton area - 188,000 acres;

(5) from Coles Island southeast to the Petitcodiac River and Bay of Fundy - 889,000 acres;

(6) from the north end of Grand Lake northeast to the Cains River - 250,000 acres; and

(7) a band along the east coast from Dorchester, north to Chatham - 789,000 acres.

In Nova Scotia, egg-mass counts at 30 locations showed an intensification of the outbreaks in western Cumberland County and on the North and South Mountains in Kings and Annapolis counties. Elsewhere, populations were generally low and the infestation appears not

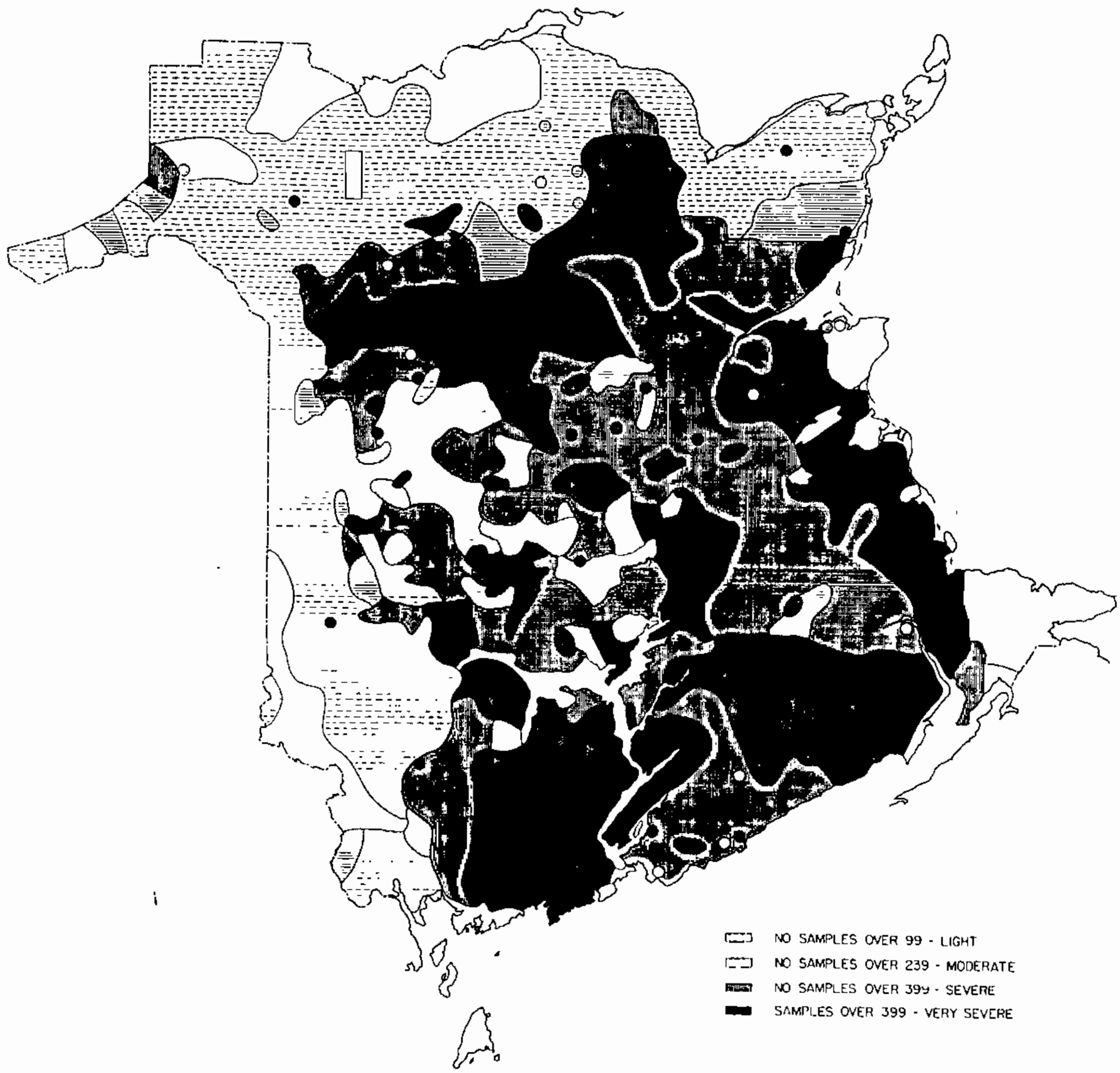

Fig. 3. Spruce budworm egg-mass infestation, 1971.

Table 9. Trends in spruce budworm populations by sector[a] from 1967 to 1971 (Number of sample points in brackets)

Area	Mean egg masses per 100 ft^2 of foliage					Egg-mass ratios			
	1967	1968	1969	1970	1971	68/67	69/68	70/69	71/70
Sprayed in 1971									
Sprayed once	130(281)	470(288)	462(313)	517(340)	392(346)	3.61	0.98	1.12	0.76
Sprayed twice	117(86)	215(94)	652(106)	718(107)	430(120)	1.84	3.03	1.10	.60
Unsprayed in 1971									
Northwest	4(111)	4(113)	5(121)	22(152)	165(169)	1.00	1.25	4.40	7.50
Northeast	13(54)	28(56)	50(70)	250(84)	425(90)	2.15	1.78	5.00	1 70
Central-west	24(94)	85(99)	121(104)	136(115)	161(113)	3.54	1.42	1.12	1.18
Southwest	3(36)	25(41)	47(43)	136(56)	234(63)	8.33	1.88	2.89	1.72
East Coast	30(70)	107(70)	304(70)	620(82)	500(86)	3.56	2.84	2.04	.81

a. See Fig. 1.

to have increased in area from 1970. The average egg-mass count for Nova Scotia was 242 (range 28 to 970) egg masses per 100 ft^2 of balsam fir foliage. A survey for overwintering budworm larvae in November and December 1971 supports the results of the egg-mass survey in Kings, Annapolis, and Cumberland counties. However, the larval survey detected a significant increase in budworm population over all of Nova Scotia. These populations are still generally low but an area of moderate infestation was detected in Lunenburg County which represents a significant southward expansion of the Kings-Annapolis counties infestation.

In western Prince Edward Island, counts of egg masses at eight locations indicate a moderate to high infestation in that area. A survey for overwintering larvae at 44 locations in Prince Edward Island supports the results of the egg-mass survey. In addition, this survey detected moderate to high infestations over the remainder of the Province, and the counts of larvae indicate a two-fold increase in the population over 1970.

Hazard to Trees in 1972

Hazard to trees for 1972 is based on:

(1) estimates of tree condition, current defoliation, previous defoliation, and egg-mass populations at each egg-mass sample location;

(2) a composite map of areas that received 2 years of defoliation (1970 & 71) as determined from aerial surveys;

(3) observations of forest conditions made from a low-flying aircraft and from the ground.

Hazard is classified into three categories and the areas on the map are general locations inside which this hazard condition is prevalent, particularly on balsam fir. These categories are:

(1) Extreme - tree mortality and extensive top-killing is expected;

(2) High - tree vigor will be reduced and top-killing is expected;

(3) Hazard variable (low to moderate) - trees more or less in fair condition. A high insect population is present. Tree vigor will be reduced and there may be top-killing in some scattered locations.

In New Brunswick, the areas of high, extreme, and variable hazard for 1971 and 1972 are shown in Table 2 and Fig. 4. The 4.7 million acres of high and extreme hazard represents an increase of 2.1 million acres over 1970-71.

In Nova Scotia, hazard is high to extreme in balsam fir stands located in the infestation areas of Cumberland, Kings, and Annapolis counties. The approximate areas inside which there are stands in a high to extreme rating are: Cumberland County - 100,000 acres; Kings and Annapolis counties - 165,000 acres.

In Prince Edward Island, hazard is generally low to moderate because of the newness of the infestation.

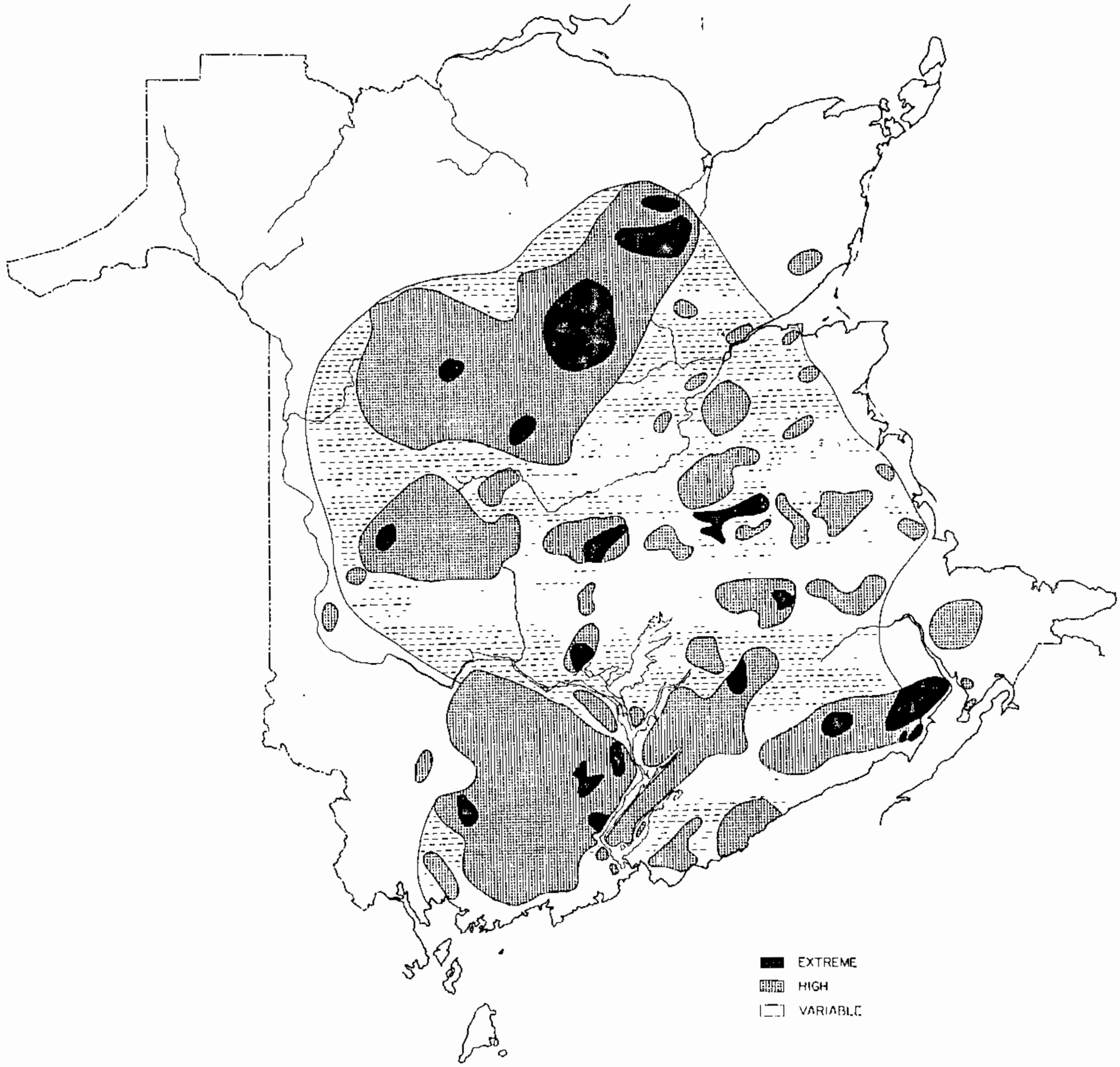

Fig. 4. Hazard to trees in New Brunswick in 1972 as a result of defoliation by the spruce budworm.

ECOLOGICAL CONSEQUENCES OF INSECTICIDE USAGE AGAINST THE SPRUCE BUDWORM IN NEW BRUNSWICK

SYNOPSIS

The Balsam Fir Community

Studies have been conducted since 1966 to determine how side-effects of insecticides applied to budworm-infested stands may influence the long-term prospects for natural regulation of spruce budworm, and whether they may affect the stability of minor pests normally kept at sparse densities by biocontrol mechanisms. Populations of minor pest species, scavengers, and epiphyte browsers, predaceous arthropods, and budworm parasites on balsam fir have been monitored both in sprayed and unsprayed areas.

Both defoliation and insecticides influence the arthropod community on fir. Population densities in sprayed plots since the introduction of fenitrothion show the following trends:

<u>Pests</u>:
- Spruce budworm - high density maintained, more or less.
- Minor defoliator pests (e.g. *Evagora*) - low density maintained.
- Twig aphids - increasing to high density.
- Scale insects - stable.
- Thrips - greatly diminished.
- Spider mites - stable.

<u>Non-pests</u>:
- Scavenger insects - one species stable and one diminished in numbers.
- Algivorous insects and mites - stable.
- Fungivorous mites - density vastly increased.

<u>Predators</u>:
- One ladybeetle species drastically reduced.
- Other groups (mirids, syrphids, pentatomids, lacewings) moderately reduced.
- Spiders - strikingly stable.
- Predatory mites - striking increase in some species.

<u>Parasitism</u>:
- Egg parasites - stable or reduced.
- Parasites of small budworm larvae - stable.
- Parasites of large larvae and of pupae - drastic reduction.

These trends suggest that:

(1) the biocontrol complex operating against the budworm has been weakened. While predators and parasites may not have much influence on the population dynamics of epidemic budworm, it is desirable to

maintain high populations of beneficial insects so that they may help to regulate budworm populations when the outbreak eventually collapses and when endemic status is resumed. Spraying may lead to higher general equilibrium levels of budworm, so that resurgence becomes more probable.

(2) So far, no minor pest is opportunistically approaching epidemic status. However, spray-induced interference with biocontrol forces leaves this possibility open.

Mortality in the Arthropod Community

Drop-cloth studies in 1971 in two sample plots showed that the greater part of the mortality of all species occurred in the first 4 days after spraying. The spruce budworm was the prime victim; however, its mortality continued for 2 weeks after spaying, even though chemical analysis failed to detect fenitrothion or metabolites in newly dead larvae after the fourth day. Other victims included large numbers of lepidopterous and sawfly larvae and enormous numbers of balsam fir twig aphids. Large numbers of perching flies (nematocerous Dipterans, etc.) were killed.

The cadavers included a wide range of parasitic and necrophagous species (ichneumonoid wasps and tachinid and muscoid flies). The numbers of parasitic adults killed were small, yet it is likely that a substantial proportion of the local population of certain species was thus removed. Among the predatory arthropods, the main victims were syrphid fly larvae of several species, together with elaterid beetle adults, lacewing larvae, and small numbers of other species. Mortality of spiders, mites, and mirids was low compared with numbers surviving on the foliage.

These results demonstrate that fenitrothion is indeed toxic across a broad range of insect species, and that it has the potential to strike particularly hard on actively flying insects.

Persistence of Insecticide Residues

The analysis of samples of three species of insects, freshly collected after knock-down, showed that fenitrothion residues rapidly diminished and could not be detected later than the fourth day after spraying. Thus the opportunity for food-chain toxicity to predatory fauna is brief.

Monitoring of DDT residues also continued, but the evidence is that the forest canopy is now shedding its residues of DDT, and henceforth biological cycling is expected to be weak and largely restricted to the soil community.

Comment

These observations suggest that ecological hazards are real, but not matured. The problem arises not from the dosage but from the huge area of spray operations, and from the recurrent applications. The reinvasion or resurgence of beneficial insects may be too slow to counter the rapid reproduction of pest insects. We need to plan in anticipation of a decade of spraying, and to expect cumulative effects on species populations.

BACKGROUND

Although the primary object of spray operations against the budworm is to preserve foliage of spruce and fir trees, homeostatic mechanisms in a mosaic of non-target ecosystems (including forest, shrub, aquatic, and even agricultural) are unavoidably influenced. Since fenitrothion is a wide-spectrum insecticide, recurrent spraying will probably cause drastic adjustments in species population distributions over the course of years; not only in the spruce-fir ecosystem, but also in those dominated by hardwoods or minor conifers. This stress may ultimately result in irruptions of minor pests released from biocontrol mechanisms. Our efforts to solve one problem by insecticides may spawn other problems in forest protection.

Current research in side-effects is concentrated on the spruce-fir ecosystem because it is the most important and because such studies will indicate the nature of the response of an arthropod community to repeated low dosages of a potent insecticide. The project has been operating since 1966--the DDT era--and the first objective has been to obtain an inventory of insects, mites, and spiders on balsam fir, and to document their population levels in various environmental circumstances. The effort to measure population change has met with varying success; the densities of common insects like budworm and twig aphids have been measured with reasonable precision. However, most insect species occur at considerably lower densities and population estimates are less reliable. Sampling methods have been designed to provide three groups of data: (1) densities of the arthropod fauna on balsam fir foliage - 20 species of minor pests and prey insects; (2) densities of predaceous forms - 30 insect and 20 arachnid species; and (3) parasitism in budworm populations - about 20 species of wasps and flies.

Although study plots have been located both inside and outside the spray area, differences in species counts cannot be unreservedly ascribed to intercession with spray. Each plot is unique with its own set of environmental parameters and the establishment of 'control' plots in the rigorous experimental sense is impossible. Therefore, conclusions from the collected data must be inferred and tentative rather than cut-and-dried fact.

BIOMASS AS A MEASURE OF COMMUNITY STATUS

Of the various criteria of insect importance, numbers are the easiest to measure, but biomass is a better index of community impact. In budworm-infested firs, the spruce budworm typically outnumbers most species populations and easily dominates the biomass inventory: for example in June, the budworm biomass may outweigh the combined biomass of all other arthropods by 1,000-fold. The next most important species in terms of biomass is the balsam twig aphid, and this species, with 10 or 20 million individuals per acre, is the staple diet of a large number of invertebrate predators." Next in biomass are the various minor lepidopterous pests such as *Evagora*. Still lower are other assorted pests and non-pests such as mites, scales, psocids, springtails, and thrips.

The biomass of all predatory arthropods on fir approximates the combined biomass of all prey insects excluding the spruce budworm. Biomass measurements list species in rather different order of abundance from measurements of numbers of individuals. Mirids and ladybeetles are relatively high in the list, but mites and spiders are relatively low in spite of their enormous numbers. These various predators help to reduce populations of budworm in the early stages (eggs, and first and second instars) but it is obvious that, in general, predators have little significance in regulating epidemic populations at any time in the season. An exception to this general statement may have been discovered in studies at Fundy Park this year. A small cecidomyiid was found to kill 80% of the third-instar budworm population in the research plot samples. In biomass terms, this predator is extremely efficient; although it is much smaller than its host, it feeds on the host blood and attacks several individuals.

POPULATION TRENDS IN KEY SPECIES

Since every species has its own characteristic seasonal curve, a single population fix for each species will not provide seasonal and perennial trends. Thus populations have been estimated from samples of the branch-dwelling community taken at 1- to 2-week intervals during May, June, and July of each year from 1966 to 1970. These results have been summarized as a series of species graphs but are not included here.

In summary, the following trends have been observed on fir in five research plots, from the late 1960's to 1971:

Phytophagous Arthropods

Spruce Budworm (*Choristoneura fumiferana*)--In infested and repeatedly sprayed plots, densities remain perennially high. In unsprayed plots, the trend is upward. A 500-fold increase between 1968 and 1969 in one plot illustrates the effect of moth flights.

Other Lepidopterous Pests--Sampling is not sufficiently sensitive to determine density changes of most species, but there does not appear to be much difference in densities between sprayed and unsprayed plots. *Evagora* spp. and *Dioryctria reniculella* have generally a tendency to increase in both classes of plot.

Balsam Twig Aphid (*Mindarus abietinus*)--Population trends have been accurately plotted. This species appears to have an oscillation of about 5 years which is largely independent of fenitrothion spray. Currently in New Brunswick, populations are close to the expected peak.

Thrips (*Taeniothrips pini* and *Oxythrips* sp.)--Population densities are somewhat lower in unsprayed areas but dramatically lower in sprayed plots since fenitrothion was used.

Scales (*Abgrallaspis ithacae* and sp. not det.)--Remarkably steady and similar in sprayed and unsprayed plots.

Spider mites (*Oligonychus ununguis* and *Pentamerismus erythreus*)--Steady and similar in both sprayed and unsprayed plots.

Orbatid mites (30 species)--A few species (e.g. *Trhypochthonius* sp.) have attained spectacular densities in infested, sprayed forest. This is a response to the availability of fungal browse on the budworm-chewed foliage, although fenitrothion-kill of some predators may contribute.

Springtails-- *Entomobrya nivalis* and *Sminthurus* sp. show steady low densities in unsprayed plots. *Sminthurus* sp. has become very scarce in sprayed plots since the introduction of fenitrothion, and *Entomobrya* is low and erratic.

Predatory Arthropods

Spiders (10 species)--Populations remarkably stable in unsprayed plots. In one sprayed plot, normal density has been resumed under the fenitrothion regime from a very low density under the former DDT regime.

Mites (many species)--Group density, moderate and stable in unsprayed plots; apparently erratic but sometimes extremely high in sprayed plots.

Mirids (10 species)--Moderately stable densities in unsprayed plots; less stable but common in sprayed plots.

Ladybeetles (2 main species)--Moderate density related to abundance of aphid prey in unsprayed plots. Sharp reduction (near extirpation) of *Mulsantina hudsonica* in sprayed plots.

Nabids (3 species)--Low density in all plots; apparently unaffected by spray regime.

Pentatomids (2 species)--Low density in all plots; especially rare in sprayed plots.

Lacewings (5 species)--Moderate density in unsprayed plots; lower in sprayed plots.

Syrphids (13 species)--Moderate density; a difficult sampling problem; somewhat reduced in spray plots.

At this stage, after only 3 years of fenitrothion spraying, and only 4 to 6 years of population sampling, I am reluctant to ascribe changes in density to spray effects. Obviously one would have to know the population dynamics of each species in detail to specify interactions. Changes in density involve the expected oscillation of a population around a mean, plus the susceptibility of that species to the spray, plus any reduction in biocontrol forces (parasites, predators), plus other food-chain effects (competition for food). Nevertheless, the evidence of near extirpation of the ladybeetle, *Mulsantina hudsonica*, plus evidence of population instability in other organisms, suggest that major changes in the faunal community can be expected if the spray program is extended in space and time.

SPRUCE BUDWORM PARASITES

A survey of budworm parasitism was conducted in New Brunswick in 1970 and 1971 because of the suspicion that hymenopterous and dipterous adults might be especially susceptible to the spray cloud. Sample plots in pole-stage, fir-spruce were selected for differences in climatic zone, insecticide history, and budworm density, and sampled at intervals across the spring. The data are currently being examined, but first impressions are: (1) the parasites of small larvae (*Glypta* spp. and *Apanteles* spp.) have maintained the same level of parasitism (about 20%) in sprayed and unsprayed areas. These parasites are killed by the insecticide in about the same proportion as their hosts when sprays are applied to fourth-instar budworm. It is possible that late sprays could cause reduction in survival of *Apanteles* adults; (2) parasitism of large budworm larvae and pupae is greatly reduced (<1%) in the plots sprayed with fenitrothion. These ichneumonoids (*Meteorus, Apecthis, Itoplectis, Phaeogenes* sp., etc.) and tachinids (*Actia, Eumea, Winthemia* sp., etc,) ordinarily provide about 10% parasitism in epidemic budworm populations; (3) egg parasite (*Trichogramma* sp.) densities have been measured, but no gross difference between sprayed and unsprayed plots has been detected. Of the parasite species that have been reduced, many are flying adults at spray time, so it is suspected that they have fallen victim to fenitrothion. The results may confirm suspicions of abnormally low large-larval parasitism in the survey of 1970 (Varty *et al.*, 1971).

Parasitism is an important factor, but by no means a key one, in the dynamics of epidemic budworm populations. Nevertheless, it is desirable that the parasite complex be sustained at high density so that it may exert an influence on the budworm populations when they eventually collapse. If parasites become very sparse under a spray regime, they may need several years in which to rebuild populations to an influential position. In the meantime, budworm populations would tend to fluctuate around a higher equilibrium level and resumption of outbreak conditions might be triggered more easily.

SPRAY-INDUCED MORTALITY IN THE ARTHROPOD COMMUNITY

To determine the range and intensity of acute toxicity of the spray to insects, drop cloths were erected in two plots to collect the bodies of poisoned insects under fir trees. These cloths were examined at 2-day intervals and the species were identified. Table 10 shows the results.

It is believed that the scarcity of ladybeetles and of adult parasites of the budworm in this plot is due to extensive reductions in their numbers in spray seasons 1969 and 1970. Small numbers of apparently healthy, large larval parasites (*Eumea* sp.) were recovered as puparia from the drop cloths, indicating again that some species are less susceptible than others.

The mortality values in Table 10 confirm that fenitrothion is indeed a wide-spectrum insecticide. The large number of predator and parasite species among the victims indicates a pronounced weakening of biocontrol mechanisms; but this will remain hypothesis until life-table studies of individual species can be conducted.

PERSISTENCE OF INSECTICIDE IN INSECTS

Yule and Duffy (1971) have shown that fenitrothion is rapidly broken down by photo-exposure, but is longer lived when absorbed in foliage. To check whether the fenitrothion persisted in the bodies of its victims, freshly dead insects were collected in the field at intervals after spray application, and analysed by Dr. Duffy (University of Prince Edward Island) for fenitrothion and its toxic metabolite, fenioxon. Fenitrothion was detected in budworm in a descending gradient until the fourth day after spraying but not thereafter. Fenioxon was not detected. This suggests that dead or dying insects may provide an oral pathway for ingestion of poison by predators (arthropods, birds, fish, amphibia, etc.) during only a few days after spraying.

It was interesting also that insecticide disappeared from victims within 4 days of spraying, although budworm mortality continued at a high rate for 2 or 3 weeks after spraying. This suggests that a delayed lethal factor is involved.

Fenitrothion was also detected in aphids and syrphids. The high level in the syrphids may indicate that the mode of locomotion or of predation is important in the vulnerability of individual species.

Studies on DDT residues have continued but are now less pressing. Data on the persistence of DDT in forest biota suggest diminishing mobility in biological cycle. The insecticide was undetectable in samples of foliage (Kettela, personal communication) and in foliage insects collected from fir and spruce in 1971, i.e. 4 years after the cessation of DDT usage. Evidently, the forest canopy is rapidly shedding its residue burden by the process of annual leaf-fall. Cycling of DDT may now be largely confined to the soil community but even there residues are now detected only in weak concentrations and in few species of organisms (carpenter ants, fireflies, slugs, earthworms, fungi, and toads); analyses of several other plants and animals have yielded no trace. DDT remains abundantly present in the soil (Yule and Smith 1971) but is largely immobile. I infer from the available evidence that local DDT persistence will present a rapidly diminishing hazard to ecological processes and to wildlife during the 1970's.

PROPOSALS FOR 1972

I feel that if insecticide usage is to be a forest management technique for the foreseeable future, then we must be prepared to go much further with side-effects studies. Ideally, we should have simulation studies of ecosystem interactions (pests - competitors - biocontrols - chemical agents); biocontrol mechanisms in the absence of spray; life-table or key-factor studies of indicator species to compare survival in spray regimes and natural circumstances; life-table

Table 10. Estimates from drop cloth counts of numbers of various arthropod groups killed on balsam fir by aerial application of fenitrothion. Plot 1 sprayed on 5 June with 3 oz./acre when budworms were at peak of third instar; Plot 2 sprayed on 16 June with 3 oz./acre when budworms were at peak of fifth instar. Tallies were made at 2-day intervals after spraying

Group	Plot 1			Plot 2		
	Insects killed (thousands per acre)	Number of species	Peak of kill (days after spraying)	Insects killed (thousands per acre)	Number of species	Peak of kill (days after spraying)
Pests						
Spruce budworm	525	1	4	1050	1	2
Other lepidopterous larvae	14	13	4	64	12	2
Sawfly larvae	21	3	4	.4	2	2
Balsam twig aphid	2000	1	4,6	–	1	–
Cinara aphids	16	2	2,4	20	2	2,8
Parasites						
Ichneumonoid adults	5	30	2	3	24	2
Tachinid adults	.2	2	2	.4	2	2
Predators						
Syrphid fly larvae	70	10	4	19	8	2
Elaterid beetle adults	9	3	4	2	3	2
Lacewing larvae	5	3	2,4	1	5	2
Hemiptera	.2	3	4	1	5	2
Spiders	1.5	9	4	3	10	2
Non-pests						
Muscoid flies	4	20+	2	6	20+	2
Nematocerous flies	16	–[a]	2	11	–[a]	2
Brachycerous flies	6	–[a]	2	20	–[a]	2
Various orders	2	–[a]	2	2	–[a]	2

a. Many species.

studies of pest mortalities relative to spray chemical candidates, dosages, formulations, and timings; and the impact of insecticides on non-target organisms. Some components of these studies could be contracted to universities as graduate studies; others would be preferable inside the C.F.S. We must aim to minimize defoliation, minimize ecosystem disruption, and maximize target-pest kill. Since our present insecticides, although highly potent, are broad-spectrum, our progress toward the ideal may be slow.

Pending initiation of a comprehensive side-effects program, I propose in 1972 to make the following studies:

(1) to monitor the faunal community (including predators and parasites) on balsam fir foliage;

(2) to initiate similar studies on red spruce and on one hardwood species;

(3) to relate acute toxicity to the fate of the spray cloud in research plots;

(4) to investigate the relationship of fenitrothion residues to insect mortality;

(5) to improve surveillance of other ecosystems;

(6) to investigate adult parasite behavior relative to sampling and insecticide responses.

The above proposal is more suited to a small team than to a single researcher.

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